FORAGE YIELD AND QUALITY OF *Pennisetum pedicellatum* VARIETIES IN RELATION TO FERTILIZER NITROGEN AND INTERCROPS

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IGFRI

INDIAN GRASSLAND & FODDER RESEARCH INSTITUTE
JHANSI (U.P.)

DEDICATED TO
THE LOVING MEMORY OF
MY RESPECTED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled " Forage yield and quality of *Pennisetum pedicellatum* varieties in relation to fertilizer nitrogen and intercrops" presented to Bundelkhand University, Jhansi (U.P) for the award of the Degree of Doctor of Philosophy in Agricultural Sciences (Agronomy) is a record of *bona fide* research work carried out by Shri Dinesh Chandra Saxena, Scientist, Central Institute of Agricultural Engineering, Bhopal, at Indian Grassland & Fodder Research Institute, Jhansi under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma or published in any other form.

It is also certified that Shri D.C.Saxena has put in the attendance required under the University's statutes during the course of present investigation.

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CONTENTS

INTRODUCTION

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Forages form the mainstay of our livestock industry to minimise the competition between human beings and animals for needed nutrients owing to land and input constraints. With the increasing animal population and shrinking land resources, the problem to provide adequate feed and forage is assuming alarming dimensions. The Policy Advisory Group on Grazing and Livestock Management of Government of India (1990) has projected the livestock population to 494 million for 2000 A.D. The requirement of green forage, dry matter and concentrates for the country's livestock population at their optimum plane of nutrition has been estimated at 837, 529 and 95 million tonnes, respectively (Singh, 1990). The National Commission on Agriculture (1976) has, however, indicated the corresponding deficit of 64, 16 and 80 per cent of the requirements. It follows that with the present feed and fodder resources in the country, we are able to meet only 46.6% of the requirement and that too by feeding poor quality roughages.

India has only 8.3 million hectares (4.4 %) of the country's cropped area under fodder crops and there is no scope of diverting good agricultural lands exclusively for forage production because of pressing need of such lands for food and cash crops. Alternatively, some of the marginal and sub-marginal lands which otherwise are not remunerative for food crop

production offer great potential to create new avenue of forage resources by growing grasses and/or legumes.

Pennisetum pedicellatum Trin. is an important grass species for forage and soil conservation. This grass is known by different names like "Dinanath", "Deenbandhu" and "Dinagrass". It grows luxuriantly on eroded and marginal wastelands as compared to other grasses. The species is well adapted to light red and low fertile soils of coastal region of West Bengal, Orissa and Bihar. Dinanath grass plays a vital role in improving water stable aggregates (Chatterjee *et al.*, 1978) and producing highest herbage yield as compared to *jowar* and *bajra* (Rathore and Kumar, 1977). Thus, it holds promise for ley farming systems under Indian conditions.

Pennisetum pedicellatum provides leafy, succulent, nutritious and palatable forage for long duration extending up to the scarcity period of October-November in North India. On an average, Dinanath grass contains 6.5 % crude protein, 3.2 % ether extract, 35.8 % crude fibre, 40.1 % nitrogen free extract and 14.4 % total ash with digestibility of feed ingredients ranging from 43 to 71 % at flowering stage (Chatterjee and Das, 1989). However, its different varieties contain varying concentration of oxalic acid, an anti-quality constituent, which depletes body calcium of animals fed on such grass. Legumes, on the other hand, contain high amount of calcium and therefore, would supplement the animal diet with additional calcium to take care of such metabolic disorder. It is also stipulated that

intercropping of Dinanath grass with forage legumes (cowpea/clusterbean) and/or adequate nitrogen nutrition may reduce the oxalate content of grass below the toxic limit. The grass, however, grows slowly in early stage and picks up growth after 40 to 50 days of seeding. During this period, the grass is generally run over by seasonal weeds which compete severely for soil moisture and plant nutrients. This calls for working out the optimum nitrogen requirement and identifying suitable intercrops to harness the production potential of Dinanath grass.

The development of varieties possessing the characteristics of high yield potential, improved quality traits with low oxalate content, responsive to fertilizer nitrogen, ous better compatibility with forage legumes and ability to fit in the existing cropping systems has have been the major research thrust areas in *Pennisetum pedicellatum*. In recent years, some of the promising strains of this grass have been evolved and many more are in the pipe line at various stages of evaluation under All India Coordinated Research Project on Forage Crops. These varieties differ in their growth rhythm, nitrogen response and compatibility with forage legumes.

Nitrogen is the key element in grass growth and is the most limiting nutrient in Indian soils. Nitrogen application not only increases the green and dry matter yields but also improves the quality of forages particularly the level of crude protein (Menhi Lal and Tripathi, 1987 a). *Pennisetum pedicellatum* has been found to respond up to 150 kg N/ha depending upon soil types,

grass varieties and crop stands (Tripathi and Singh, 1991). Translated into practice it means that Dinanath grass requires higher amount of nitrogen for luxuriant vegetative growth, early bulking of the crop and quick regeneration following cutting/defoliation.

The nitrogen nutrition of grass species however, received little attention in our country owing to major emphasis on grain crops. Therefore, mixed/intercropping of grass with forage legumes is being advocated to economise the costly input of fertilizer nitrogen. Moreover, intercrops provide protein rich forage, build up soil fertility and improve the physical edaphic environment. Further, such intercropping systems offer great scope for developing energy efficient and sustainable production strategy with less use of market purchased inputs (Swaminathan, 1991).

As a result of concerted efforts at Indian Grassland and Fodder Research Institute, Jhansi, superior varieties of *Pennisetum pedicellatum* viz., Bundel-1, Bundel-2 and IGFRI-3808 have been released for cultivation throughout the country. These varieties however, differ considerably in their adaptability to dry land environment, productivity potential, nutrient requirement, associability with forage legumes, fertilizer use efficiency and herbage quality.

The scientific information on the combined effect of nitrogen nutrition and legume association in realizing potential yield, regulating forage quality and reducing oxalate

content in *Pennisetum pedicellatum* varieties is rather meagre. Since, agronomical management strategies in forage crops aim at increasing herbage yield per unit area per unit time alongwith improvement in quality traits to take care of two biological systems viz., 'Soil-plant' and 'Plant-animal', the present investigation entitled "Forage yield and quality of *Pennisetum pedicellatum* varieties in relation to fertilizer nitrogen and intercrops" was undertaken at Indian Grassland and Fodder Research Institute (IGFRI), Jhansi (U.P.) with the following objectives:

1. To study the growth behaviour, productivity and quality of promising varieties of *Pennisetum pedicellatum* as pure and intercropped with forage legumes at different levels of nitrogen.
2. To find out the response of pure and mixed stands of *Pennisetum pedicellatum* to varying levels of fertilizer nitrogen.
3. To test the feasibility of nitrogen economy and the extent to which the quality traits of *Pennisetum pedicellatum* could be regulated through legume association.
4. To identify the most productive combination of *Pennisetum pedicellatum* variety, intercrop and fertilizer nitrogen for higher herbage yield and nutrient outturn per unit area per unit time.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter presents a comprehensive review of the available literature on the comparative performance of *Pennisetum pedicellatum* varieties and their response to nitrogen nutrition in pure stand as well as intercropped with cowpea or clusterbean in terms of growth characters, forage yield and quality traits. The key issues on its amplitude of adaptability, compatibility with forage legumes for nutritional quality and nitrogen economy have also been covered in this section.

Environmental Adaptability of Dinanath Grass:

The grasses have wide range of variability with respect to type of growth, response to different methods of management, breeding behaviour, edaphic adaptation and other important characteristics (Musser *et al.*, 1948). The name of genus *Pennisetum* is derived from the latin word "Penna" feather and "Seta" a bristle and the species *pedicellatum* represents having a small stalk of spikelets. The origin of this grass seems to be India. Its occurrence is reported in the hills of Chhotanagpur, Bihar (Haines, 1924), hills of Bihar, Rajputana, Orissa and Western peninsula (Blater and McCann, 1935) and Madhya Pradesh (Khan, 1957). *Pennisetum pedicellatum* grass is known by different names like "Dinanath", Deenbandhu", Deena" and Dinagrass. A number of ecotypes were isolated in India from the seed samples obtained from Nigeria (Chatterjee and Kumar, 1964).

Its fodder value was first recognized in Australia (Oyenuga, 1957). In India, it is considered as a good forage crop in the states of Assam (Mukherjee, 1969-70), West Bengal (Chatterjee *et al.*, 1973), Bihar (Mukherjee and Chatterjee, 1955), Uttar Pradesh (IGFRI, 1972), Punjab (PAU, 1970), Haryana (Singh and Arora, 1970; Relwani and Bagga, 1968), Orissa (Mandal and Vamadevan, 1978; 1983), Maharashtra (Desai and Deore, 1977) and Madhya Pradesh (Khan, 1957). The species was claimed to be a palatable forage grass grazed by sheep, goats and cattle (Chatterjee and Das 1989).

Dinanath grass is a high yielding, quick growing, luscious, leafy and thin stemmed grass. As a high yielding short duration grass it fits well in cropping systems between two arable crops. In case of monocropping of Dinanath grass usually one cut is taken after 80-90 days of sowing and then the crop is left for seed production.

Systematic research on this grass was initiated at Sabor Agricultural College, Bihar in 1953 (Mandal and Chatterjee, 1953; Chatterjee *et al.*, 1954). In India, Chatterjee and Richharia (1955) were the earliest workers to investigate agronomical and ecotypic differences in *Pennisetum pedicellatum*. The plant type and their growth characters were further elaborated by Mukherjee and Prasad (1958), Sharma (1966), Chatterjee and Pillai (1970), Chatterjee and Reddy (1975) and Patil and Ghosh (1959-63).

Dinanath grass prefers a good moist soil during its active growth period. However, it also grows well in eroded marginal wastelands, banks of marshy areas and poor soils but gives much higher yields on fertile well drained loams receiving annual rainfall of 500 to 1500 mm. The grass is not suitable for flood prone areas and cold temperate regions. The grass grows well both in acidic as well as sodic soils. Dinanath grass can be grown in acidic soil without liming. It can also tolerate soil salinity of 12 mmhos/cm and soil pH ranging from 5.5 to 8.0 (IGFRI, 1984).

Dinanath grass has acquired a special place amongst *kharif* forages in many parts of the country. High tonnage, low water requirement, resistant to diseases and pests, good seed setting with no damage by birds are some of the points which go in favour of this grass (Bose, 1965; Chatterjee and Singh, 1967; Relwani and Bagga, 1968; Rathore and Kumar, 1977).

Bose (1965) reported that in sandy soil of Dumaraon (Bihar) Dinanath grass outyielded pearl millet recognized as promising crop of the locality. Singh and Arora (1970) recorded green forage yield of Dinanath grass as high as 800-1000 q/ha against 200-470 q/ha yield from maize, sorghum and pearl millet at Hissar. The yield levels of Dinanath grass in terms of green forage have been reported to be 1000 q/ha in West Bengal (Mukherjee *et al.*, 1976) and up to 1285 q/ha in Orissa (Mandal and Vamadevan, 1978). One more selected strain (T-15) of Dinanath grass significantly outyielded (700-800 q/ha) some of

the high yielding forages like *jowar* (300-400 q/ha) in green forage production (Singh, 1982).

Comparative Performance of *Pennisetum pedicellatum* Varieties:

Growth behaviour and forage yield: The varietal trials on *Pennisetum pedicellatum* conducted at various centres under All India Coordinated Research Project on Forage Crops in the last one decade provided very useful experimental evidence on their relative growth and productivity (AICRPFC, 1981-82 to 1988-89).

In 1981-82, significant variation in plant height was observed at Hissar and Rahuri but not at Jorhat. However, varieties did not differ significantly in number of tillers at any location in 1981. Variety Bundel-1 produced more Leaves leaf than other varieties. IGFRI-3808 and Bundel-1 produced highest green forage yield of 153.7 and 446.0 q/ha at Anand and Hissar, respectively. The corresponding dry forage yields were 29.2 and 104.4 q/ha.

In 1982-83, variety Bundel-1 ranked second in plant height at Rahuri. Significant variation in green forage yield was recorded at Urulikanchan, Rahuri, Hyderabad and Jhansi. Variety Bundel-1 at Rahuri gave the highest green forage yield. The overall mean of the centre showed that variety Bundel-1 ranked third in green forage production. In case of dry matter, the differences were significant at Urulikanchan and Rahuri and not at Jhansi.

In 1983-84, at Urulikanchan variety Bundel-2 produced tallest plant of 200.1 cm whereas, JP-1 resulted in shortest plant of 152.3 cm. However, Bundel-1 and IGFRI-3808 produced plant height of 160.5 and 179.3 cm, respectively. Variety IGFRI-3808 produced 117.7 tillers per metre row length followed by Bundel-1 (89.0 tillers) and Bundel-2 (76.7 tillers) per metre length at Urulikanchan. The data on number of days taken to attain 50 % flowering at Urulikanchan was 89 days for Bundel-1, 85 days for IGFRI-3808 and 82 days for Bundel-2.

Significantly higher dry matter yield was recorded with variety IGFRI-S-4-1-2 (177.2 q/ha) followed by Bundel-2 (174.6 q/ha). Bundel-1 producing 133.8 q/ha dry matter was statistically at par with variety IGFRI-3808 (145.9 q/ha).

In 1984-85, at Rahuri variety IGFRI-S-2-2-2 ranked first (250.6 cm) in plant height followed by Bundel-1 (190.0 cm) and Bundel-2 (185.6 cm). Variety IGFRI-3808 produced plant height of 143.0 cm. At Jabalpur variety Bundel-2 ranked first (241.0 cm) in plant height, whereas, variety IGFRI-3808 ranked 5th (204.0 cm) and Bundel-1, 10th (123.0 cm). The highest leaf:stem ratio occurred with variety IGFRI-S-4-1-2 followed by IGFRI-S-32-1. Variety Bundel-1 gave lowest leaf:stem ratio. Varieties IGFRI-3808 and Bundel-2 showed almost similar leaf:stem ratio (0.44 and 0.42). Variety Bundel-1 took 88 days in attaining 50 % flowering stage whereas, varieties Bundel-2 and IGFRI-3808 took only 80 days at Jabalpur. The dry matter yields of variety Bundel-2 (71.8

q/ha), IGFRI-3808 (71.7 q/ha) and Bundel-1(70.3 q/ha) were at par but significantly higher than JP-13 (46.2 q/ha), IGFRI-S-56-1(45.5 q/ha) and JP-1 (39.2 q/ha). Green forage yield of different varieties did not differ significantly at any location of central zone. However, on the basis of pooled data Bundel-1 produced higher green forage yield of 212.4 q/ha as compared to Bundel-2 (209.4 q/ha) and IGFRI-3808 (190.8 q/ha). In case of dry forage production, Bundel-2 outyielded IGFRI-3808 and Bundel-1.

In 1985-86, variety Bundel-2 ranked second in plant height at Rahuri. Variety Bundel-1 and IGFRI-3808 produced similar (96.7) number of tillers per running metre. Variety Bundel-1 took 95 days in attaining 50 % flowering stage whereas, variety IGFRI-3808 took only 82 days. Variety Bundel-1 ranked 2nd in leaf:stem ratio (0.36) and minimum leaf:stem ratio (0.20) occurred with IGFRI-S-2734. In green forage production, variety Bundel-2 performed better and ranked third at Rahuri, Bundel-1 performed better at Urulikanchan and ranked third. IGFRI-3808 ranked second at Jabalpur but scored first over the centres. In case of dry matter yields, varieties differed significantly at Rahuri and Jabalpur and not at Urulikanchan. Bundel-2 ranked third at Urulikanchan, Bundel-1 ranked fifth at Urulikanchan and Rahuri and IGFRI-3808 ranked third at Jabalpur. Variety IGFRI-3808 registered significantly highest crude protein yield (15.6 q/ha) and excelled out IGFRI-S-56-1, IGFRI-S-2734 and IGFRI-S-31-1. On the basis of pooled data over the centres variety Bundel-2

produced highest crude protein yield (10.2 q/ha) followed by Bundel-1 (8.9 q/ha).

In 1986-87, variety Bundel-1 produced highest green forage yield at Rahuri. Bundel-2 produced highest green forage at Jhansi followed by Bundel-1. On the basis of pooled data over the zones, Bundel-2 ranked second in green forage production. However, varieties differed significantly in green forage production at Rahuri, Jhansi and Jabalpur and not at Akola and Urulikanchan. In case of dry forage, variety Bundel-2 produced highest yield at Jhansi, Akola and Jabalpur. On the basis of pooled data over the zones, variety Bundel-2 ranked second in dry forage production. The highest crude protein yield was recorded with IGFRI-S-2-2-2 followed by Bundel-2 (13.8 q/ha) at Urulikanchan and by Bundel-1 (8.7 q/ha) at Rahuri. The data averaged over the locations in 1986-87 produced crude protein yields in order of IGFRI-S-2-2-2 > IGFRI-S-56-1 > Bundel-2 > Bundel-1.

In 1987-88, at Jabalpur, variety Bundel-1 recorded tallest plant of 162.2 cm followed by JP-13 (159.3 cm). Maximum leaf:stem ratio was obtained with Bundel-2 followed by IGFRI-S-56-1. Variety Bundel-1 produced significantly highest green forage yield at Jabalpur. On the basis of pooled data over the zones, Bundel-2 ranked second in green forage as well as dry matter production. Variety Bundel-2 produced significantly higher crude protein yield (4.6 q/ha) as compared to Bundel-1 (3.9 q/ha).

Advanced varietal trials on Dinanath grass with nine entries in 1988-89 revealed that Bundel-2 produced tallest plants. Varieties Bundel-1, BDN-1 and TNDN-1 were observed to be late flowering. Variety JHP-2 produced highest green forage yield as compared to other entries including Bundel-1 and Bundel-2 in all the zones and on all India basis. In terms of dry matter production, variety Bundel-2 (174.6 q/ha) proved significantly superior over Bundel-1 (138.8 q/ha) which in turn did not differ significantly from IGFRI-3808 (145.9 q/ha). In crude protein yield, variety Bundel-2 ranked second. Moreover, variety JHP-1, JHP-2 and Bundel-2 had high neutral detergent fibre (NDF) content than other entries.

Chemical composition and quality traits: Singh and Arora (1970) reported that Dinanath is relished by animals just like sorghum. The chemical composition of the grass on dry matter basis at flowering stage is as 6.5 % crude protein, 3.2 % ether extract, 35.8 % crude fibre, 40.1 % nitrogen free extract, 14.4 % total ash, 85.7 % organic matter, 0.4 % calcium and 0.3 % phosphorus.

The crude protein content of Dinanath grass is equivalent to sorghum and other graminaceous forages of *kharif* season harvested at flowering stage. The crude protein content ranged from 3.5 to 6 % in 12 genotypes of *Pennisetum pedicellatum* harvested at 95 days of growth (Das and Arora, 1976). However, a range of 6-10 per cent crude protein has been reported at preflowering to flowering stage (Bose, 1965; Singh and Arora, 1970; Das *et al.*, 1974; Pal *et al.*, 1975).

The most notable feature of the grass is its low content of oxalic acid, i.e., 1.7 % against 2.5 % in *bajra* and 6.0 % in Napier grass. In Assam, Mukherjee (1970) recorded 0.42 kg of digestible protein and 3.55 kg of starch equivalent in 45.35 kg of green forage. Feeding of this grass to local bullocks ensured highly positive nitrogen balance and satisfactory phosphorus retention but calcium balance was slightly negative. Banerjee *et al.* (1973) recorded slightly negative nitrogen balance and marginally positive calcium balance in black Bengal goat.

Upadhyay *et al.* (1978) reported that the digestibility of dry matter, organic matter and nitrogen free extract of Dinanath grass was satisfactory in Barbari goats. Nutrient balance study indicated that there was negative balance of nitrogen and phosphorus and positive balance of calcium.

Digestibility of crude protein, ether extract, crude fibre, nitrogen free extract, dry matter, organic matter, digestible crude protein and total digestible nutrients were 48.5, 43.5, 71.1, 59.0, 59.5, 63.3, 2.9 and 58.6 per cent, respectively.

Oyenuga (1957) and Paul *et al.* (1981) reported the superior nutritive value of the grass. They analysed the grass for proximate constituents at different stages of growth and found that its crude protein percentage was high and the rate of deterioration of digestibility appeared to be greater than perennial grasses, i.e., Napier, Rhodes grass etc.

The chemical composition and physical properties of Dinanath grass vary with stages of crop growth. Protein content decreased

whereas, structural carbohydrate increased with age. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were negatively correlated with *invitro* dry matter digestibility (Johri *et al.*, 1975; Paul *et al.*, 1981; Das and Arora, 1976).

The digestibility co-efficients for organic matter and crude protein were reported to be 69-73 and 63-65 per cent, respectively. The hemicellulose and cellulose contents in Dinanath grass were almost equal to other species of genus *Pennisetum* (Das *et al.*, 1978).

Intercropping of *Pennisetum pedicellatum* with Forage Legumes:

In the recent past the cereal-legume intercropping is gaining importance both in temperate and tropical regions of the world (Searle *et al.*, 1981; McCollium, 1982; Allen and Obura, 1983; Chui and Shibles, 1984). This may be due to some of the established and speculated advantages of intercropping systems such as higher grain yields, greater land use efficiency per unit land area, and improvement in soil fertility through the addition of nitrogen by fixation and excretion from component legumes (Agboola and Fayemi, 1972; Willey, 1979; Eaglesham *et al.*, 1981). The intercropping of legumes with cereals offers scope for developing energy efficient and sustainable agriculture (Papendick *et al.*, 1976; IAEA, 1980). In forage farming, the grass + legume intercropping increases forage yield, improves herbage quality, reduces the risk of anti-quality constituents and economises fertilizer nitrogen (Tiwana and Bains, 1976).

Dinanath grass is grown either as a pure crop or in mixture with forage legumes such as cowpea, ricebean and clusterbean. Dinanath grass performs well under mixed cropping in alternate 30 cm apart rows with cowpea or ricebean and thus provides quality forage for dairy cattle (Mukherjee *et al.*, 1982).

Intercropping with legumes provides additional forage besides improving the quality of herbage. The legumes are rich in protein and also improve soil fertility by fixing atmospheric nitrogen varying from 100-200 kg/ha (Ostrowski, 1972).

Growth rhythm and forage yield: Chatterjee *et al.* (1978) reported that Dinanath grass and legumes yielded green forage of 450 q/ha and 250 q/ha, respectively. The intercropping system provides leafy, succulent, nutritious and palatable forage for longer duration extending up to the scarcity period of October to November in North India.

Das and Chatterjee (1976) found optimum leaf area index of 7.5 in Dinanath grass for intercepting 95 per cent of incident light. At low N level of 20 kg/ha, higher dry matter accumulation was observed up to 80 days in mixed cropping of Dinanath grass + ricebean/cowpea than pure grass.

Investigation by Senthivel *et al.* (1991) concluded that in pure stand, Dinanath grass produced highest green and dry forage yields. Cowpea in pure stand recorded higher crude protein yield over Dinanath and *guar.* Dinanath grass and cowpea cross sown at full seed rate registered highest green and dry forage yields as well as crude protein production over other combinations.

Higher forage and crude protein yields under mixed cropping of Dinanath grass + cowpea at full seed rates were also obtained by Tripathi (1989) in rainfed *vertisols.*

Das and Chatterjee (1977) studied the nature of competition between Dinanath grass and legumes-cowpea/ricebean both in summer and rainy seasons. Summer growth of grass tends to suppress the legumes while during rainy season the viny legumes suppress the grass. They also observed nitrogen economy in forage production through mixed cropping of grass and legumes with 20 kg N/ha and adequate quantity of P and K fertilizers. Eighty days after sowing, Dinanath grass + cowpea yielded as much dry matter as that of pure Dinanath grass obtained with 75-100 kg N/ha in dry season and 25-35 kg N/ha in wet season. The crude protein yield was highest with 160-190 kg N/ha in dry season and with 50-80 kg N/ha in wet season.

The trial conducted under All India Coordinated Research Project on Forage Crops (AICRPFC, 1984-85 to 1986-87) concluded that in 1984-85 the green and dry forage yields obtained from pure stand of *Pennisetum pedicellatum* (271.4 q green and 61.5 q dry matter/ha) and with cross sowing Dinanath grass and cowpea (237.6 q green and 54.7 q dry matter/ha) were significantly higher than pure cowpea (58.1 q green and 15.4 q dry matter/ha), Dinanath grass + cowpea in row ratio of 1:1 (152.6 q green and 32.8 q dry matter/ha), 2:2 (205.2 q/ha green forage) and 2:1 (203.9 q green and 46.9 q dry matter/ha). The green forage yield in 2:2 planting pattern was statistically at par with that of

2:1. *Pennisetum pedicellatum* pure as well as in combination with cowpea showed significantly higher green and dry forage yields as compared to cowpea pure. In 1985-86, the highest green and dry forage yields were recorded with cross sowing of Dinanath grass and cowpea at Kanke, Vellayani and Jabalpur, while at Palampur and Coimbatore highest green forage yield was obtained with pure Dinanath grass. In 1986-87, out of seven crop combinations, Dinanath grass + cowpea was found most productive. The trial conducted at Kanke recorded the highest green and dry forage yields with cross sowing of Dinanath grass and cowpea followed by alternate rows of Dinanath grass + cowpea (1:1) and paired rows (2:2) of Dinanath grass + cowpea.

Chatterjee and Roquib (1986) observed that Dinanath grass grown during mid July to mid October gave the highest green forage yield of 45.6 t/ha as compared to maize + cowpea grown during February to March (37.8 t/ha). Prasad (1986) reported that perennial Dinanath grass + *Stylosanthes* mixture proved superior over thin napier grass + *Stylosanthes* for hilly areas of Bihar.

Nutrient outturn and forage quality: The mixed cropping of Dinanath grass with cowpea or ricebean in alternate paired rows recorded increased forage yield, higher land equivalent ratio (LER), greater crude protein outturn and fertilizer use efficiency as compared to sole cropping (Tripathi *et al.*, 1984).

Tripathi (1989) also reported higher crude protein yield under mixed cropping systems of sorghum/pearl millet/ *Pennisetum pedicellatum* with cowpea and *guar*. Intercropping of Blue panic grass either with cowpea or *guar* resulted in the highest total crude protein outturn (Singh *et al.*, 1984).

Studies on the effect of fertilizer application and legume introduction on the productivity of *Dicanthium annulatum* pasture revealed that the maximum dry matter yield of 69.6 q/ha was obtained with 60 kg N + 30 kg P_2O_5/ha followed by the introduction of *Stylosanthes hamata* fertilized with 30 kg P_2O_5/ha (67.5 q/ha). However, crude protein yield was maximum (5.67 q/ha) with grass + *Stylosanthes hamata* + 30 kg P_2O_5/ha followed by grass + *Macroptelium atropurpureum* + 30 kg P_2O_5/ha indicating that *Stylosanthes hamata* was more suitable for introduction in *Dicanthium annulatum* as compared to other legumes. The mixed stands, need to be fertilized with 30 kg P_2O_5 per hectare for getting the higher yield of quality forage (Rai, 1988). The beneficial effect of grass-legume mixture over pure stand has also been documented by Chauhan and Faroda (1979) and Rai and Kanodia (1982).

Narwal *et al.* (1988) reported more green forage yield in mixture of seed of legume and cereal and drilled in same row (22.03 t/ha) and intercropping (21.2 t/ha) as compared to monoculture of soybean (20.07 t/ha), cowpea (18.23 t/ha) and pearl millet (13.05 t/ha). Cowpea + pearl millet mixture gave maximum green forage yield (22.57 t/ha) than other cropping

systems. Crude protein content of pearl millet was increased when sown in mixture (8.18 %) and intercropping (8.52 %) as compared to its monoculture (7.77 %). Likewise, crude protein content of mixed forage grown in mixture (9.19 %) and intercropping (11.03 %) was greater than that of pure pearl millet fodder (7.77 %). However, voluntary dry matter intake, total digestible nutrients, dry matter digestibility and metabolizable energy of mixed fodder were similar when grown in mixture or intercropping systems.

Singh and Singh (1986) on the basis of three years of experimentation on buffel grass (*Cenchrus ciliaris linn.*) found higher crude protein content, *invitro* dry matter digestibility and lower cell wall constituents when grown as buffel grass + *guar*, buffel grass + cowpea and buffel grass + fodder moth bean than buffel grass + grain clusterbean, buffel grass + grain cowpea, buffel grass + grain moth bean or its pure stand. However, buffel grass + fodder clusterbean and buffel grass + grain moth bean excelled the other cropping systems for crude protein and *invitro* dry matter digestibility of the buffel grass. Singh, (1983) found that intercropping of cowpea with *anjan* grass increased the forage production of the latter considerably. The lowest crude protein content was recorded with pure *anjan* grass. Maximum crude protein content was recorded with intercropping of cowpea.

Mixed cropping improved the quality of herbage by increasing the protein content (Patel *et al.* , 1973) and reducing the level

of toxic constituents viz., oxalate in Dinanath grass. Tiwana and Bains (1976) also reported reduction in anti-quality factor like oxalic acid due to introduction of leguminous fodder crops in hybrid Napier.

Effect of Nitrogen Nutrition on *Pennisetum pedicellatum*:

Nitrogen is the key element in crop growth and is the most limiting nutrient in Indian soils. The paramount importance of nitrogen for increasing herbage yield has been widely accepted. The major portion of the N taken up by plants is used in synthesizing protein. About 10-30 % of the total N in grasses will be found in non protein N (NPN) form. Tropical grasses have been reported to grow better than their temperate counterpart at low level of N. Nitrogen application not only increases the green and dry matter yields but also influences the quality of forage, particularly the level of protein (Menhi Lal and Tripathi, 1987 a).

Nitrogen exercises favourable effects on growth attributes (plant height and number of leaves), palatability characteristics (leaf:stem ratio), quality parameters (protein and fat) and herbage yield of graminaceous forage species (Bajwa *et al.*, 1983; EL-Kassaby, 1985; Wani *et al.*, 1991).

Forage yield and quality in relation to nitrogen nutrition:

Dinanath grass is highly responsive to nitrogenous fertilizer (Bose, 1965; Mukherjee *et al.*, 1976; Rathore and Kumar, 1977; Pal *et al.*, 1975). Application of 49 kg N through FYM and 45 kg/ha through fertilizer produced 92 q/ha dry matter in single cut of

Dinanath grass. Top dressing of nitrogen at 4 weeks growth stage gives good results. In pure stand, 80 to 100 kg N/ha in two splits (half basal + half top dressed after 6 to 8 weeks of growth) may be applied. Application of 40 kg N/ha after every cutting is conducive for regrowth. At Hissar increasing levels of N up to 120 kg/ha and phosphorus up to 60 kg P_2O_5/ha increased both green as well as dry forage yields (Narwal *et al.*, 1977).

Mukherjee *et al.* (1976) reported that nitrogen up to 150 kg/ha increased the dry matter yield (133 q/ha) significantly. The optimum dose of nitrogen for Dinanath grass was found to be 145 kg N/ha. The cost:benefit ratio of fertilizer application was 10.2 and 9.5 at 100 and 150 kg N/ha, respectively.

In some of the studies conducted at Indian Grassland and Fodder Research Institute, Jhansi, Dinanath grass has been found to respond up to 120 Kg N/ha in pure stand (Menhi Lal and Tripathi, 1987 a). Abraham *et al.* (1980) concluded that application of nitrogen to Dinanath grass was beneficial for increasing yield and quality. They also reported that highest level of nitrogen (150 kg/ha) produced significantly higher forage yield than lower level of N (50 kg/ha).

Pandey and Dwivedi (1992) concluded that the plant height in Dinanath grass increased with increasing levels of nitrogen up to 120 kg/ha. The increase in plant height due to nitrogen application was also reported by (Cheema *et al.*, 1975). The number of tillers were 39.2/hill at 90 kg N/ha and 40.7/hill at 120 kg N/ha. The number of leaves/plant as well as leaf length

increased due to application of nitrogen over control treatment both in single cut and double cut systems. Application of 90 and 120 kg N/ha produced leaves of 103.2 and 100.7 cm length. The green and dry forage yields of Dinanath grass significantly increased due to increase in nitrogen level up to 90 kg/ha. This has also been supported by Rathore and Kumar (1978).

A linear increase in green forage yield of 2.8, 2.2, and 0.6 q/ha was observed with each kg of nitrogen applied to Dinanath grass PP-10, PP-3 and sorghum JS-20, respectively. A linear increase in green and dry forage yield was obtained consistently with the application of 80 and 160 kg N/ha over control treatment (Tiwari, 1965; Sinha and Chatterjee, 1966; Narwal, 1970).

The studies conducted under All India Coordinated Research Project on Forage Crops (AICRPFC, 1975-76, 1981-82, 1985-86, 1986-87, 1991-92) on the performance of *Pennisetum pedicellatum* in relation to nitrogen and phosphorus requirements revealed significant effect up to 150 kg N/ha at Kanke and Anand in terms of green forage yield in 1975-76. However, at Hyderabad significant increase was observed only up to 100 kg N/ha. In dry matter production, the significant response was obtained up to 150 kg N/ha at Kanke and up to 200 kg N/ha at Anand. In 1981-82, Dinanath grass produced significantly higher green forage yield (274.1 q/ha) at 100 kg N/ha which was at par with 150 kg N/ha (294.1 q/ha). However, significantly highest dry matter yield (99.3 q/ha) occurred at 150 kg N/ha. In 1985-86, significantly highest green and dry forage yields were observed

at 100 kg N/ha as compared to control treatments, however, the variation between the control plots and 50 kg N applied plots was not significant. In 1986-87 also, a linear increase in green and dry matter yield was observed due to increase in nitrogen from 0-100 kg N/ha. The experiment conducted at Palampur, Bhubaneshwar and Kanke in 1991-92 brought out that both green and dry forage yields differed significantly due to varying nitrogen levels from 0-90 kg/ha.

Nitrogen application increases crude protein and metabolizable energy but narrows down the nutritive ratio of forage (Menhi Lal and Tripathi, 1987 a). Studies conducted at Indian Grassland and Fodder Research Institute, Jhansi revealed higher forage as well as crude protein yield of range grasses due to the application of nitrogen ranging from 30-90 kg N/ha (Rai and Kanodia, 1981; Kumar *et al.*, 1979; Kumar *et al.*, 1980; Dwivedi *et al.*, 1980).

Kumar *et al.* (1980) reported linear response to nitrogen up to 90 kg/ha, resulting in 135 % increase in dry matter and 153 % increase in crude protein yield of *Cenchrus setigerus* over control treatment.

Bhati and Singh (1982) summarised that the dry matter and crude protein yields increased significantly with the application of N up to 60 kg/ha. Forage yield attributes, viz., plant height and number of tillers as well as uptake of N and P increased significantly with the same nitrogen dose.

Rai and Kanodia (1981) found significant increase in crude protein yield (540.7 kg/ha) with nitrogen application of 120 kg/ha. The investigation on the effect of N on dry matter yield and quality of *Cenchrus ciliaris* x *Cenchrus setigerus* hybrid grown in pure and mixed with *Stylosanthes hamata* under rainfed condition at Jhansi (Rai, 1991) revealed that the highest dry matter (10.99 t/ha) and crude protein (1.16 t/ha) yields were obtained with 60 kg N/ha in pure stand which were significantly higher than the yields obtained with mixed stand receiving up to 30 kg N/ha. However, the crude protein content of grass was higher in mixed stand at all the levels of N than pure stand. On an average crude protein content of grass was higher (8.4 %) in mixed stand than pure stand.

Nitrogen Economy Through Grass + Legume Intercropping:

In fixing atmospheric N_2, legumes contribute to the N content of soil either as sole crops in rotation or as intercrops (LaRue and Patterson, 1981). In such systems, legumes may either increase the soil N status through fixation and excretion or in the absence of an effective N_2-fixing system, compete for N (Trenbath, 1976).

The quantity of N_2 fixed by the legume component in cereal legume intercropping depends on the species, morphology, density of legume in the mixture, the type of management, and the competitive abilities of component crops.

The literature on nitrogen transfer suggests that N_2 fixed by the intercrop legume may be available to the associated cereal in current growing season (Agboola and Fayemi, 1972; Remison, 1978; Eaglesham *et al.*, 1981; Pandey and Pendleton, 1986) or as a residual N for the benefit of a succeeding cereal crop (Nair *et al.*, 1979; Searle *et al.*, 1981; Singh, 1983). Both forms of N transfer are considered to be important and could improve the N economy of various legume based intercrop systems.

Roots and nodules of legumes are thought to be the important sources of N transfer because of their high N contents (Butler and Bathurst, 1956). In cowpea, Minchin *et al.* (1978) found N from these sources only 6 % of the total plant N, this may be inadequate to produce any substantial N benefit for a subsequent crop. From pot studies, Peoples *et al.* (1983) reported that N from roots and nodules of cowpea were 13 % of the total plant N.

The degree to which N from intercropping legume may benefit a cereal crop depends on the quantity and concentration of the legume N, microbial degradation (mineralization) of the legume residues, utilization of these residues, and the amount of N_2 fixed by the legumes (Henzell and Vallis, 1977; Herridge, 1982). The rate of mineralization of organic N, determined by microbial activity, is primarily influenced by the prevailing moisture and temperature regimes (Ladd and Amato, 1984).

Ofori and Stern (1987) evaluated the N economy of maize-cowpea intercropping system using both N natural abundance and N labelled fertilizer methods. They found that cowpea maintained

its ability to fix atmospheric N_2 when intercropped with maize, but that N_2 fixation was reduced by N fertilizer application. The comparable P values (percentage of N derived from atmospheric N_2) of the intercrop cowpea with or without applied N was attributed to greater N uptake by the associated maize, which induced the companion cowpea to be more symbiotic.

Rai *et al.* (1980) obtained maximum forage production with the introduction of phasybean (*Macroptelium lathyroides*) followed by field bean (*Lablab purpureus*) with nitrogen equivalence of 129.9 and 121.1 %, respectively. This in turn, indicated that with the introduction of these two legumes in *Sehima-Heteropogon* grassland, the dry matter yield can be increased equivalent to that obtained with 40 kg N/ha. Similarly, Rai (1985) reported that the intercropping of legume in buffel grass increased the total forage yield which was equivalent to the application of 60 kg N/ha.

The studies at Indian Grassland and Fodder Research Institute, Jhansi revealed that intercropping of Dinanath grass with cowpea and clusterbean fertilized with 55 kg N + 45 kg P_2O_5 per hectare produced herbage yield equivalent to pure grass receiving 90 kg N + 30 kg P_2O_5 per hectare but gave 1.5 times more outturn of crude protein per unit area indicating that intercropping supplemented 35 kg N with an additional application of only 15 kg P_2O_5 per hectare (Menhi Lal and Tripathi, 1987 a).

There are three main sources of nitrogen in cereal-legume intercrop systems. These are, N fixed by the legume component

from the atmosphere, from fertilizer, and from soil. The data published by Eaglesham *et al.* (1981) in Western Nigeria and Ofori and Stern (1987) in Western Australia offer some scope for illustrating N budgeting studies with maize and cowpea. Using equation suggested by Rennie *et al.* (1982) to calculate N from fixation, from fertilizer, and from soil, a N balance sheet was constructed for such a system with the data of Eaglesham *et al.* (1981). The densities of component crops, as sole crops were 60,000 plants/ha of maize, 1,10,000 plants/ha cowpea, the intercrop density was half of each sole crop density.

The N contributed by seeds of maize and cowpea at sowing was less than 2 kg/ha, fixed N_2 by intercrop cowpea was about 41 kg/ha and N from fertilizer was 3 kg/ha. The total N in the crops was about 99 kg/ha, consisting of N from seeds, fertilizer, N_2 fixation, and 53 kg/ha from the soil. Assuming a seed N harvest index of 36 % for cowpea and 90 % for maize, the quantity of N removed in the intercrop system was about 52 kg/ha, 28 kg/ha from maize and 24 kg/ha from cowpea. The N remaining in residues was 46 kg/ha.

The observations that the efficiency of cereal-legume intercropping relative to growing crops separately is greatest at low level of N, suggest that at low N, the intercrop legume has a greater dependence on atmospheric N_2 and presumably, competition from the associated cereal is minimised.

The production efficiency of cereal-legume intercropping could be enhanced through the use of more effective strains of

Rhyzobia and low rates of fertilizer N so as to maximize N_2 fixation of the intercrop legume. This will partially eliminate competition for N between cereals and legumes as intercrops. To meet the high N requirements of the intercrop cereal while at the same time promoting N_2 fixation of the companion legume, slow release fertilizers might be used. This renders the N available to the cereal at about the peak vegetative stage, presumably after the N_2-fixing system of the legume has become well established.

MATERIALS AND METHODS

MATERIALS AND METHODS

The materials used and techniques employed in the conduct of field experiments and laboratory determinations have been described in this chapter.

Experimental Site and Soil Characteristics:

The field investigation was conducted for two consecutive years during *kharif* (rainy) season of 1989 and 1990 at the Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi (U.P.). The soil of the experimental field was *Parwa* type of Bundelkhand region covered under the order *Alfisol*. *Parwa* soil represents a kind of mixed red and black soil, medium in texture and water holding capacity. The soil is prone to crust formation following rains. The soil fails to support plant growth if drought spell of 2-3 weeks prevails even under mild evaporative demand. Before the start of the experiment composite soil samples were collected from the experimental field from 0 to 15cm depth and were subjected to physico-chemical analysis (Table 1). The soil of experimental field was sandy clay loam in texture and neutral in reaction. The soil analyzed low in organic carbon as well as available nitrogen, medium in available phosphorus and high in available potassium.

Table 1. Physico-chemical characteristics of the soil of the experimental field

Characteristics	Value	Method and Reference
Mechanical composition		Bouyoucos hydrometer method (Bouyoucos, 1962)
Sand (%)	48.0	
Silt (%)	21.6	
Clay (%)	30.4	
Textural class	Sandy clay loam	
Field capacity (%)	24.2	Pressure plate apparatus (Richards, 1947)
Wilting point (%)	8.4	Pressure membrane apparatus (Richards, 1954)
Available moisture (mm m^{-1})	220.6	Pressure plate apparatus (Richards, 1947)
Bulk density (g cm^{-3})	1.4	Core sampler (Piper, 1950)
Soil pH (1:2.5::soil:water)	7.3	Combined glass electrode pH meter (Jackson, 1958)
Electrical conductivity (dSm^{-1} at $25^{o}C$)	0.18	Solubridge method (Richards, 1954)
Organic carbon (%)	0.47	Walkley and Black's rapid titration method (Jackson, 1958)
Available nitrogen (kg N/ha)	210.0	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available phosphorus (kg P/ha)	18.2	Olsen's method (Olsen *et al.*, 1954)
Available potassium (kg K/ha)	390.0	Flame photometer method (Toth and Prince, 1949)

Weather Conditions:

Jhansi is situated at 25^{o} 27' North of latitude and 78^{o} 35' East of longitude, 271 metres above mean sea level in semi-arid tract of Plateau and Hill Region of India. The rainfall varies from 800 - 1100 mm with annual mean of 936 mm. The potential evapotranspiration goes as high as 1400-1700 mm resulting in moisture index value of -40 to -50. The rainfall is erratic and more than 90 % of the rainfall is received within 10 weeks from July to mid September with many intermittent long dry spells. The total rainfall is received in less than 50 rainy days. The winter rains are meagre and uncertain. Drought is a rule rather than exception in Jhansi. The drought in the month of June and September is expected once in three years and in July and August once in seven years. Two consecutive years experience drought in twelve years. Monsoon generally commences by the last week of June but sometimes is delayed to the first week of July. The active monsoon usually withdraws by mid September.

The average annual temperature of the place is usually high and there is a vast variation between maximum and minimum temperatures. The highest temperature in May and June sometimes touches a value of 48^{o}C. Such a high temperature coupled with windy days results in high potential evapotranspiration. This often causes standing crops to wilt even though the soil moisture regime may not be very low. The mean weekly values of

meteorological parameters for the crop periods in 1989 and 1990 are presented in Table 2 and illustrated in Fig. 1a and 1b.

The rainfall during crop period was 487.5 mm in 1989 and 844.1 mm in 1990. These rains were received in 15 and 31 rainy days in respective years indicating that rains were well distributed in the second year. The year 1989 experienced long drought spell from standard week No. 36 beginning from September 3 and active monsoon practically ceased. On the other hand, in 1990 the cessation of monsoon started from standard week No. 40. The relative humidity in 1989 varied from 66 to 92 per cent for period I and from 22 to 73 per cent for period II. The corresponding values in 1990 ranged from 76 to 94 and 41 to 80.

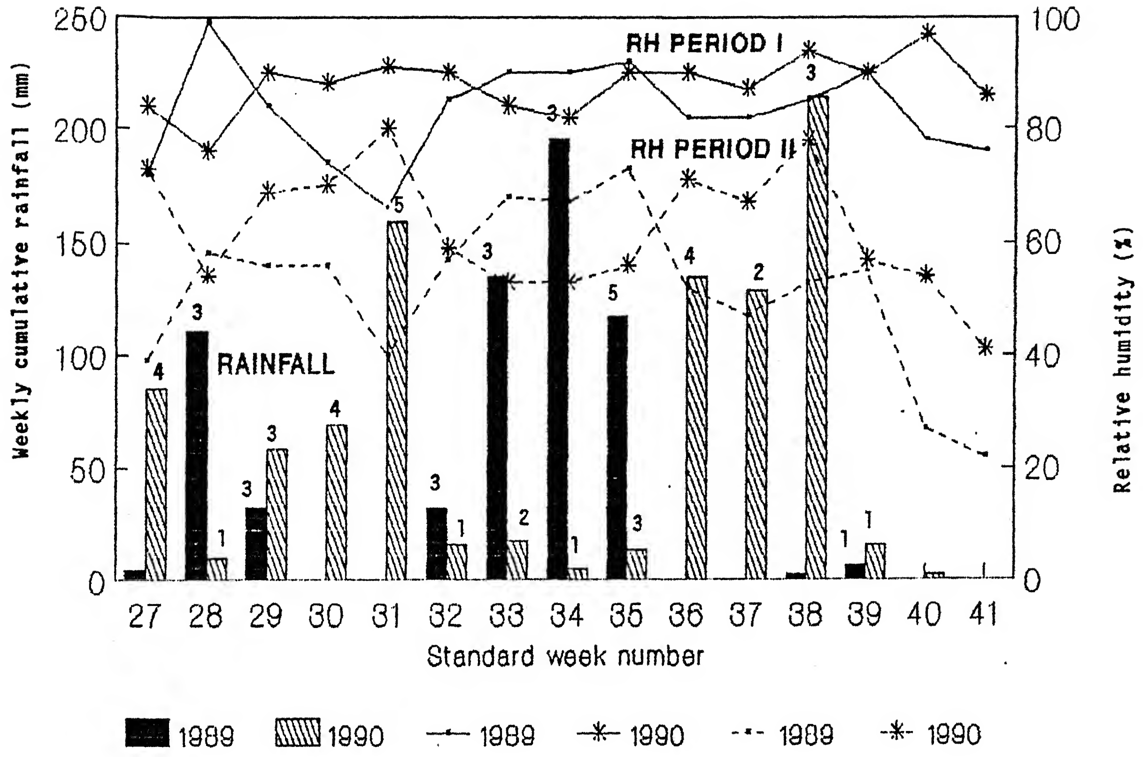
The maximum and minimum temperatures ranged respectively from 30.4 to 36.9^{o}C and 18.8 to 28.8^{o}C in 1989 and from 28.0 to 33.4^{o}C and 18.7 to 26.3^{o}C in 1990. The mean weekly evaporation varied from 1.9 to 6.5 mm in 1989 and from 2.4 to 5.6 mm in 1990. The minimum evaporation occurred in the standard week No. 33 in 1989 and in standard week No. 38 in 1990. The maximum values of evaporation were recorded in standard week No. 41 and 33 in respective years.

Table 2. Weekly mean meteorological data during crop periods of 1989 and 1990

Standard week number	Week starting from	Weekly cumulative rainfall (mm)		Number of rainy days		Relative humidity, %				Temperature, °C				Pan evaporation (mm)	
						Period I		Period II		Maximum		Minimum			
		1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
27	Jul. 2	4.5	85.3	-	4	72	84	39	73	36.9	30.4	25.5	25.0	NA	4.8
28	Jul. 9	110.4	9.6	3	1	99	76	58	54	35.2	32.2	26.1	26.3	NA	4.9
29	Jul. 16	31.9	58.7	3	3	84	90	56	69	35.4	32.7	26.3	24.3	NA	4.1
30	Jul. 23	0.0	68.9	0	4	74	88	56	70	34.1	30.5	28.8	25.0	NA	3.4
31	Jul. 30	0.0	159.2	0	5	66	91	40	80	34.8	29.1	26.6	23.5	NA	4.3
32	Aug. 6	31.5	15.8	3	1	85	90	57	59	34.5	32.8	25.1	25.2	4.9	3.3
33	Aug. 13	134.7	17.2	3	2	90	84	68	53	30.5	32.6	24.3	24.9	1.9	5.6
34	Aug. 20	195.5	5.0	3	1	90	82	67	53	32.8	33.4	25.1	24.6	3.3	3.9
35	Aug. 27	117.0	13.6	5	3	92	90	73	56	30.9	33.2	24.1	24.7	3.7	4.8
36	Sept. 3	0.0	134.6	0	4	82	90	52	71	32.7	30.6	23.7	23.8	5.3	3.3
37	Sept.10	0.0	129.1	0	2	82	87	47	67	34.6	31.9	23.3	24.4	5.4	3.7
38	Sept.17	2.5	213.9	-	3	85	94	53	78	34.0	28.0	24.2	23.1	4.5	2.4
39	Sept.24	6.3	15.7	1	1	90	90	55	57	32.9	32.1	22.7	22.9	4.3	4.0
40	Oct. 1	0.0	2.8	0	1	78	87	27	54	36.3	32.5	19.8	21.1	5.7	4.1
41	Oct. 8	0.0	0.0	0	0	76	86	22	41	36.5	33.1	18.8	18.7	6.5	4.3
Total rainfall during crop period		487.5	844.1												

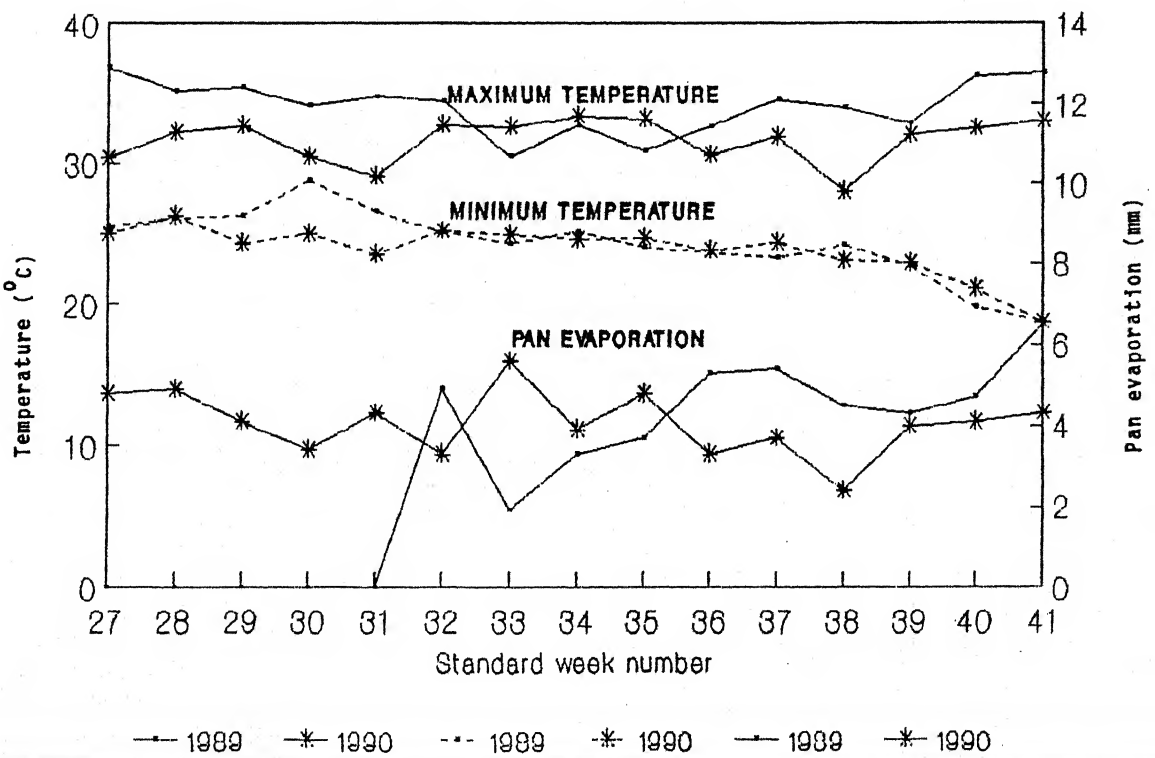
Period I and Period II denote relative humidity at 07:16 and 14:16 hours, respectively.
- denotes rainfall in traces and NA indicates data not available.

FIG 1a: WEEKLY CUMULATIVE RAINFALL AND MEAN RALATIVE HUMIDITY FOR CROP PERIODS IN 1989 AND 1990



Figures at the top of the bar indicate number of rainy days

FIG 1b: WEEKLY MEAN TEMPERATURES AND PAN EVAPORATION FOR CROP PERIODS IN 1989 AND 1990



Cropping History of the Experimental Field:

The cropping history of the experimental field is given below:

Year	*Kharif*	*Rabi*
1988	Clusterbean	Oat
1989	Experimental crops:	Oat
	Pennisetum pedicellatum	
	Pennisetum pedicellatum + cowpea	
	Pennisetum pedicellatum + clusterbean	
1990	As in 1989 mentioned above	Oat

Field Preparation and Experimental Layout:

The experimental field was prepared by ploughing with tractor drawn cultivator and cross discing with disc harrow followed by planking. Layout of the experimental field was done by making drainage channels and plot bunds. Each plot was levelled to avoid stagnation of water and tilled to ensure good seed bed for fluffy seeds. The plan of layout is given in Fig. 2. The treatment combinations were allocated to different plots using Fisher and Yate's random table.

FIG 2: PLAN OF LAYOUT

	VCN	VCN	VCN	VCN	VCN	VCN	
	123	232	221	312	132	123	
B3	311	213	322	321	213	231	B6
	131	333	112	222	111	333	
	332	223	212	212	233	122	
B2	133	321	231	221	113	323	B5
	111	313	122	332	131	311	
	132	121	312	211	112	232	
B 1	113	233	331	223	331	322	B4
	323	222	211	313	133	121	5m
		R_1			R_2	45m	

N

V - Varieties
1: Bundel-1
2: Bundel-2
3: IGFRI-3808

C - Crop stands
*1: Pennisetum pedicell*atum pure
*2: Pennisetum pedicell*atum+cowpea
*3: Pennisetum pedicell*atum+clusterbean

N - Nitrogen levels (kg/ha)
1: 30
2: 60
3: 90

R1 - R2 : Replications
B1 - B6 : Blocks

Experimental Details:

Treatments:

A. *Pennisetum pedicellatum* varieties	:(V): 3
IGFRI-S-43-1 (Bundel-1)	:V1
IGFRI-S-4-2-1 (Bundel-2)	:V2
IGFRI-3808	:V3
B. Crop stands	:(C): 3
Pennisetum pedicellatum pure	:C1
Pennisetum pedicellatum + cowpea (2:2)	:C2
Pennisetum pedicellatum + clusterbean (2:2)	:C3
C. Nitrogen levels (kg/ha)	:(N): 3
30	:N1
60	:N2
90	:N3
Total treatment combinations	:3X3X3 = 27
Experimental design	:3^3 partial confounding
Replications	:Two with 6 blocks each of 9 plots
Total No. of plots	:54
Plot size : Gross	:5.0 m X 4.5 m = 22.5 m^2
Net	:4.0 m X 4.0 m = 16.0 m^2

Characteristics of *Pennisetum pedicellatum* Varieties:

IGFRI-S-43-1 (Bundel-1): This variety is a selection from an indigenous material collected from Madhya Pradesh. It was recommended for release in 1986. It is widely adapted variety for the whole country. The height of the plant ranges from 200 to 225 cm. It flowers between 100 and 110 days after sowing (DAS) and attains maturity between 140 and 150 days. Thus, it is a late maturing variety.

The variety has high field resistance to leaf spot, *Helminthosporium* and other diseases. It has considerably high degree of resistance to major insect pests. Bundel-1 is drought hardy, responsive to high fertilization and lodging resistant. It has high tillering ability and good regeneration capacity. The variety is capable of giving 2 to 3 cuts under high fertility situations. The average green forage yield ranges from 60 to 70 t/ha. IGFRI-S-43-1 is better in forage quality with high crude protein and *invitro* dry matter digestibility.

IGFRI-S-4-2-1 (Bundel-2): This variety is a mutant progeny of exotic material pedigree 3808-4-2-1 from France. Bundel-2 was recommended for release in 1988 for whole country. The plant height ranges from 175 to 200 cm. It flowers between 80 and 85 days and attains seed to seed maturity between 125 and 130 days. Thus, it is an early maturing variety. This variety possesses considerably high tolerance to leaf spot, *Helminthosporium* and other major diseases. It has fairly high resistance to major insect pests. It is drought hardy, responsive to fertilizers and resistant to lodging. It has high tillering and good regeneration ability. On an average, it can produce green forage of 55-70 t/ha. Also, it is superior in quality as it contains high crude protein content and better dry matter digestibility.

IGFRI-3808: This variety has good popularity with farmers in different agro-climatic zones of the country owing to its high production potential and superior quality. It is a prolific seed

producer. The plant height ranges from 175 to 200 cm. It flowers between 80 and 85 days and matures between 115 and 120 days. This variety is an early type and is highly tolerant to leaf *Helminthosporium* and major insect pests. It is tolerant to drought, resistant to lodging and highly responsive to fertilizers. It has good tillering and regeneration ability. This variety is capable of giving 2-3 cuts under high fertility situations.

Characteristics of Intercropped Legumes:

Cowpea (*Vigna unguiculata* L.) 'Walp', variety HFC-42-1: It is a selection from strain No. 42. This variety was released in 1975 for general cultivation in Haryana and was recommended for whole country in 1976. It is an excellent variety for mixed cropping due to its quick and erect growing nature. The variety is moderately resistant to mosaic and also resistant to major insect pests. It has dark green foliage. It yields about 32 t green and 7.5 t dry matter/ha. It has high protein content (18 %). Its fodder is highly palatable and nutritious. The seed is small in size and creamish white in colour. The variety flowers in 60 days and attains maturity between 110 and 115 days.

Clusterbean (*Cyamopsis tetragonoloba* Taub.), variety IGFRI-212: The variety IGFRI-212 (Bundel *guar*) is a fodder cum seed type. It is a single plant selection from indigenous material from Rajasthan. This variety has been recommended for entire *guar* growing areas but most suited for cultivation in arid and semi-

arid zones of the country. The plant height ranges from 95-115 cm. It flowers between 80 and 85 days and matures between 120 and 135 days. The variety comes under medium group of maturity. It is moderately resistant to bacterial blight and also resistant to major insect pests. It is resistant to lodging and seed shattering, and responsive to fertilizers. Its fodder is highly palatable and nutritious for all kind of livestock. Its digestibility is around 72 per cent. The average green and dry matter yield is 27.4 t and 5.8 t/ha, respectively.

Fertilizer Schedules:

Nitrogen as per the treatments, was applied in the form of urea containing 46 % nitrogen as per the schedule given below:

Nitrogen levels (Kg/ha)	Dose (kg/ha) at sowing	Top dressing of N (kg/ha) Days After Sowing	
		20	40
30	10	10	10
60	20	20	20
90	30	30	30

Besides, all the plots received basal fertilizer dose of 40 kg P_2O_5 + 30 kg K_2O/ha through single super phosphate and muriate of potash, respectively. The basal dose of fertilizers as indicated above was placed in furrows below the seed. The top dressing of urea was done along the grass rows by mixing it with friable moist soil.

Sowing:

Pennisetum pedicellatum varieties as pure stand were sown in lines 25 cm apart using a seed rate of 6 kg/ha. Each grass variety was also inter-cropped with cowpea (HFC-42-1) and clusterbean (IGFRI-212) in 2:2 grass:legume paired rows 25 cm apart in replacement series using the proportionate recommended seed rates. Cowpea @ 30 kg and clusterbean @ 25 kg seed/ha were used. The sowing was done through *Kera* method on July 25 in 1989 and on July 7 in 1990. After a week, thinning and/or gap filling was done to maintain optimum plant population.

Crop Management:

As an effective weed management practice one interculture operation and one manual weeding at 30 days after sowing was provided. During the period of heavy rains however, excess water was drained to provide well drained conditions.

Harvesting:

The crop was harvested plot-wise for green forage by labours with the help of sickle at pre-flowering stage of grass. The grass and legume components were harvested on October 13 in 1989 and September 29 in 1990 and their forage yield was recorded separately. Thus, the crop duration worked out to be 80 days in 1989 and 84 days in 1990.

Observations Recorded:

Plant Population:

Plant population per running metre was counted from randomly selected three places in each plot at the harvesting stage. Number of shoots per linear metre in case of grass and number of plants per running metre in legumes were recorded. The average plant population per running metre was worked out for grass and legume components separately.

Growth characters: The observations on growth characters were recorded at forage stage before harvesting the crop. The following biometrical measurements were taken on five plants randomly selected in each plot.

Plant height: The height of five grass shoots in each plot was measured in centimetres and averaged out. The height measurement was taken from ground level to the base of fully opened leaf and/or to the base of panicle depending upon the stage of a particular plant. In case of legumes, the plant height was measured from base to the tip of plants.

Number of functional leaves : The green leaves of five tillers in case of *Pennisetum pedicellatum* and five plants in case of cowpea and clusterbean were counted and reported as number of functional leaves per tiller or per plant.

Length and breadth of leaves: These measurements were taken for grass component only. For this, third leaf from the top was selected from five plants on which height measurement was taken.

The maximum length and breadth of such leaves were measured in centimeters.

Leaf area: The area of individual grass leaf was determined in cm^2 using the following formula advocated by Yogeswara Rao *et al.* (1966):

$$\text{Leaf area } (cm^2) = \text{length (cm)} \times \text{breadth (cm)} \times 0.75$$

for Sorghum/grass.

The leaf area of cowpea and clusterbean was, however, determined by planimeter.

Leaf area index (LAI): Leaf area index is the area of leaves per unit land area. It was calculated by dividing total leaf area with land area as given below:

$$L\,A\,I = \frac{\text{Leaf Area}}{\text{Land Area}}$$

Leaf:stem ratio: At harvest, the plants drawn for the measurement of growth characters were utilized for determining the leaf:stem ratio. For this, the leaves were separated out from the stem (shoot). The fresh weight of leaves and stem was recorded separately. The leaf weight was divided by stem weight to arrive at leaf:stem ratio.

Relative leaf turgidity per cent: The relative turgidity or relative water content (RWC) of leaves was determined by the method described by Shaw and Laing (1966). For this the third leaf from the top was taken as the representative one. Such three leaves from three tillers/plants per plot were sampled just before harvesting and their fresh weight was recorded. These

leaves were dipped in water over night to allow them to become fully turgid. After taking out from water, the turgid weight was recorded. The leaves were then dried in oven at $80^{o}C$ for constant weight. Finally, the dry weight was taken and the relative turgidity percentage was calculated by the following formula:

$$\text{Relative leaf turgidity \%} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

All the weights were expressed in grams.

Root biomass: Root biomass of grass varieties was studied just after harvesting. Soil mass from 25cm x 25 cm area keeping the grass plant in centre was dug out from 0-15 and 15-30 cm depth from 3 randomly selected places from each plot. Thus the volume of the soil for root biomass studies works out to be 9375 cm^3 for 0-15 or 15-30 cm and 18750 cm^3 for cumulative depth of 0-30 cm. The roots were washed with water from the whole soil mass through a 2 mm sieve. The root biomass thus collected was oven dried and weighed separately for both the depths. These weights were added to arrive at total root biomass of 0-30 cm depth.

Nodulation in forage legumes: To determine the number of nodules in legume component, 3 samples from 25 cm X 25 cm X 30 cm representing a soil volume of 18750 cm^3 were collected randomly from each plot and the whole soil mass was taken out. The roots were separated from the soil by washing with gently flowing

water. On washed out roots the nodules were counted and averaged out.

Dry matter content: At harvesting, plant samples of each crop component weighing 200 g were collected from each plot in paper bags. These samples were dried in hot air oven at $80^{o}C$ for 48-72 hours to get constant weight. After taking the dry weight, the dry matter percentage was worked out.

Green Forage Yield:

After harvesting the produce of component crops (*Pennisetum pedicellatum*, cowpea and clusterbean) was weighed separately in kilograms for net plot size. In case of intercropping treatments, the yields of grass and legume were added to obtain total forage yield. The yields obtained from individual plots were converted and expressed as green forage yield in q/ha.

Dry Matter Yield:

The plot-wise data on green forage yield for component crops were multiplied with corresponding dry matter percentage to obtain dry matter yield in kg/plot which were later on converted to q/ha. The total dry matter yield in intercropping system was worked out as it was done for green forage yield.

Per Day Productivity:

The productivity per day in terms of green forage and dry matter yields was worked out by dividing the total yields with respective crop duration. The productivity was expressed as q/ha/day.

Chemical Analysis :

At the time of harvesting, the plant samples drawn for the estimation of dry matter content from each plot were processed and subjected to chemical analysis for determination of crude protein (CP), water soluble carbohydrates (WSC), oxalate content as well as fibre fractions. The procedures for determination of quality parameters are described below:

Crude protein (CP): The total nitrogen content in the plant sample was determined by micro-Kjeldahl method (A.O.A.C., 1970). For this, 0.5 g sample was transferred in Kjeldahl flask and digested in 10 ml of concentrated H_2SO_4 using catalyst mixture (K_2SO_4 and $CuSO_4$ in the ratio of 20:1). The digested material was transferred to 50 ml volumetric flask with distilled water and the volume was made up to the mark. An aliquot of 5 ml was distilled with 40 % NaOH and the ammonia liberated was absorbed in 10 ml of 4 % boric acid containing Tashano's mixed indicator (bromocresol green and methyl red). The distillate was titrated with standard (N/10) H_2SO_4. Nitrogen was calculated using the expression 1 ml of N/10 H_2SO_4 = 0.0014 g of nitrogen. Crude protein content was computed by multiplying the nitrogen percentage with a factor of 6.25. The total outturn of protein was calculated by multiplying dry matter yield with corresponding crude protein percent.

Water soluble carbohydrates (WSC): The content of water soluble carbohydrates was determined by method of Johnson *et al.* (1966). To determine water soluble carbohydrates in plants, 0.2 g of dry

plant samples were shaken with 100 ml of distilled water in a shaking machine, then 1 g of activated charcoal was added and the contents were filtered. From the filtrate, an aliquot of 2 ml was taken in a test tube and 2 drops of phenol (80 %) and 5 ml of concentrated H_2SO_4 were added to it. After shaking, the tubes were allowed to stand for 20 minutes. Then the optical density was measured on Spectronic-20 spectro-colorimeter at 490 um and the concentration of water soluble carbohydrates was determined from the standard curve.

Oxalate content: The total oxalate content in plant samples was determined by Peach and Tracey (1955) method. To determine the oxalate content 2 g dried plant sample was boiled in 100 ml 1N hydrochloric acid and refluxed for 15 minutes. After cooling, it was filtered through dry filter paper. 12.5 ml filtrate was taken in a centrifuge tube and 2.5 ml phosphotungstate reagent (prepared by dissolving 24 g sodiumtungstate in water, adding 40 ml syrupy phosphoric acid (sp. gr. 1.75) and diluted to 1 litre) was added. The contents were mixed and kept for 5 hours, centrifuged for 10 minutes at 3000 rpm. Then 10 ml centrifuged supernatant solution is taken in another centrifuge tube and ammonia (sp. gr. 0.88) is added drop by drop till alkaline, followed by 3 ml calcium chloride buffer (containing 25 g anhydrous calcium chloride in 500 ml 50 per cent (v/v) glacial acetic acid + 300 g sodium acetate in 500 ml water, pH 4.5). The content was mixed and kept over night in refrigerator, centrifuged for 15 minutes and washed by wash solution (A 5 % v/v

solution of acetic acid kept over calcium oxalate at room temperature) duly filtered before use. After carefully removing the washings through centrifuging, the precipitate was dissolved in 2.5 ml of 10 % H_2SO_4 and was titrated against standard N/50 potassium permanganate solution to determine the oxalic acid content using the following formula :

$$1 \text{ ml } 0.02N\ KMnO_4 = 0.0009 \text{ g oxalic acid}$$

Determination of Fibre Fractions:

Processing of plant samples: Plot wise samples on which dry matter determination was undertaken, were ground into fine powder by 'Willey mill'. For estimating fibre fractions, 27 composite samples were prepared by thoroughly mixing the samples of the corresponding treatment combinations from both the replications. These samples were subjected to the determination of fibre fractions in duplicate and the values were averaged out. The procedures for estimation of various fibre fractions are described below:

Neutral detergent fibre (NDF): Neutral detergent fibre was determined by the method of Van Soest and Wine (1967). A 0.5 g sample was weighed in 600 ml spout less beaker. To this, 100 ml of neutral detergent solution (30 g sodium lauryl sulphate, 18.61 g EDTA (sodium salt) 6.81 g sodium tetraborate decahydrate and 4.56 g disodium hydrogen phosphate and 10 ml 2-ethoxy-ethanol in one litre distilled water) and 2 ml of Decalin (decahydro-napthalin) and 0.5 g of sodium sulphite were added. The content

were refluxed for 60 minutes and filtered into a tared sintered glass crucible (porosity G1). The contents were washed thoroughly with hot water followed by acetone twice. The crucibles were dried at 100^{o}C for 24 hours in a thermostatically controlled hot air oven, weighed and ignited at 500^{o}C in a Muffle furnace for 4 hours and reweighed after cooling. Neutral detergent fibre (ash free basis) was calculated.

Acid detergent fibre (ADF) : Acid detergent fibre was determined by Van Soest method (1963). The procedure for ADF estimation was similar to that of NDF estimation except that 2 g sample was taken instead of 0.5 g and acid detergent solution (2 % solution of cetyltrimethyl ammonium bromide in 1N H_2SO_4) was used in place of neutral detergent solution and no sodium sulphite was used.
Acid detergent lignin (ADL): Acid detergent lignin was determined by the method of Van Soest (1963). To the ADF residue in the crucible, 72 % sulphuric acid was added to cover the contents. The crucible was then stirred with glass rod to make a smooth paste, breaking all lumps. The glass rod remained in the crucible and stirring continued at an hourly intervals by adding 72 % H_2SO_4 as and when it drained out. After 3 hours, the acid was filtered and the contents were washed with hot water to make acid free. The crucible was dried at 100^{o}C for 8 hours and weighed after cooling. The crucible was kept in Muffle furnace at 500^{o}C for 4 hours and weighed after cooling.

Hemicellulose and cellulose: These fibre fractions were computed using the following formulae:

Hemicellulose = Neutral Detergent Fibre - Acid Detergent Fibre

Cellulose = Acid Detergent Fibre - Acid Detergent Lignin

Acid insoluble ash content (Plant silica): Ash remaining after the ignition of lignin in the estimation of ADF is being reported as acid insoluble ash or plant silica.

Nutrient Uptake:

The uptake of nitrogen at harvest stage was computed treatment wise by multiplying dry matter yields with the corresponding nitrogen contents and the values were expressed in kg/ha.

Statistical Analysis:

Analysis of variance and test of significance : The data on various growth characters at harvest and forage yields were subjected to statistical analysis by the method of "Analysis of variance" as advocated by Fisher (1948). However, the data on quality parameters pertaining to single replication were statistically analyzed as in case of factorial experiment treating the mean sum of squares due to variety X crop stand X nitrogen (8 d.f.) as error. The two factor interactions were tested for significance. The significance of treatment effect was tested with the help of variance ratio (F value). The values of SEm$\pm$ and critical difference (CD) were worked out by the

following formulae for judging the significance of difference between two treatment means:

$$SEm\pm = \sqrt{VE/n}$$

where, VE = Error variance; n = number of observations

$$\text{Critical difference (CD)} = \sqrt{2} \times SEm\pm \times t \text{ at } 5\,\% \text{ for error d.f.}$$

Fitting of response functions: In order to determine the nature of response of *Pennisetum pedicellatum* varieties to nitrogen in pure and mixed stands,linear and quadratic components were tested for significance. The response equations were developed and curves fitted by the techniques of least square difference.

Graphical representation of data: The data obtained on various aspects under the investigation have suitably been depicted through graphs, histograms and curves developed by Harvard Graphics on WIPRO GENIUS-486(T) computer wherever necessary in order to illustrate the experimental findings.

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

This Chapter presents the results on the performance of *Pennisetum pedicellatum* varieties as pure stand and intercropped with cowpea and clusterbean as well as brings out the influence of nitrogen nutrition on growth, yield and quality of component crops. The data on crude protein, water soluble carbohydrates, oxalate content and fibre fractions are given as measures of forage quality. The response functions are presented to illustrate the nature of response to fertilizer nitrogen for *Pennisetum pedicellatum* varieties in pure and mixed stand with forage legumes.

Growth and Development of Component Crops :

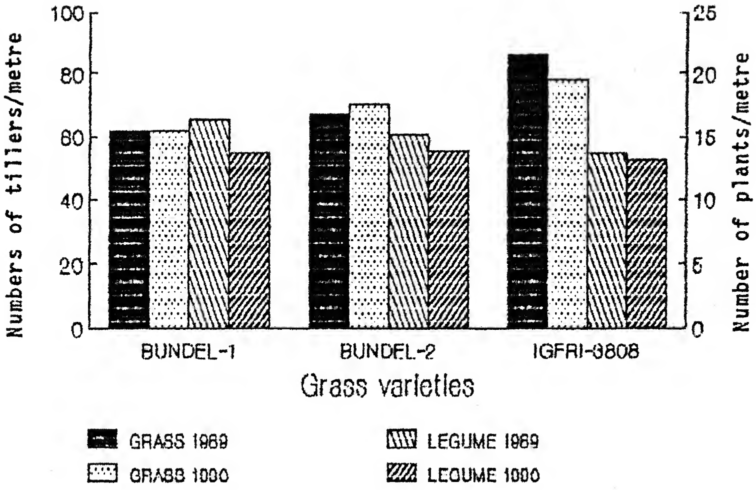
Number of tillers/plant population: The number of tillers per running metres (m) in *Pennisetum pedicellatum* and number of plants/running metre in legumes at harvest were more in 1989 than in 1990 (Table 3 and Fig. 3). In 1989, variety IGFRI-3808 produced significantly more number of tillers per running metre than Bundel-1 and Bundel-2 whereas in 1990, it was at par with Bundel-2. The variation between Bundel-1 and Bundel-2 in respect of number of tillers was not significant in both the years. The plant population of legumes intercropped with Bundel-1 was higher than intercropped with Bundel-2 and IGFRI-3808 in 1989 but not in 1990.

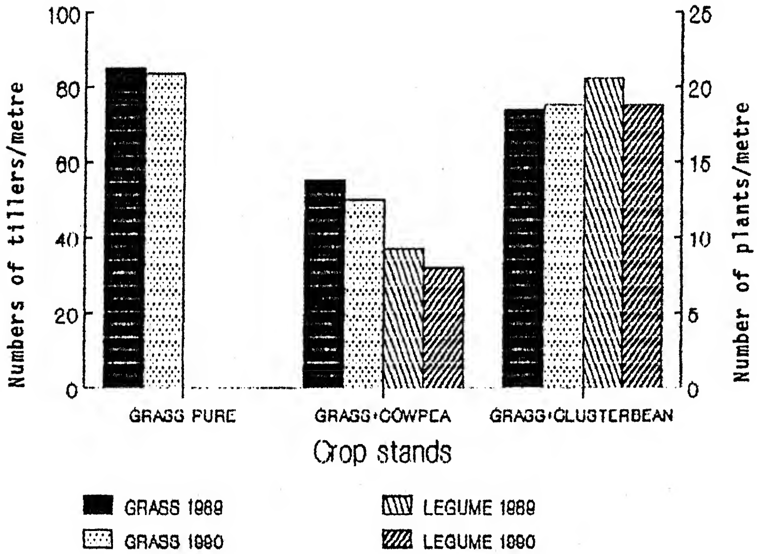
Table 3. Number of tillers/plants per running metre

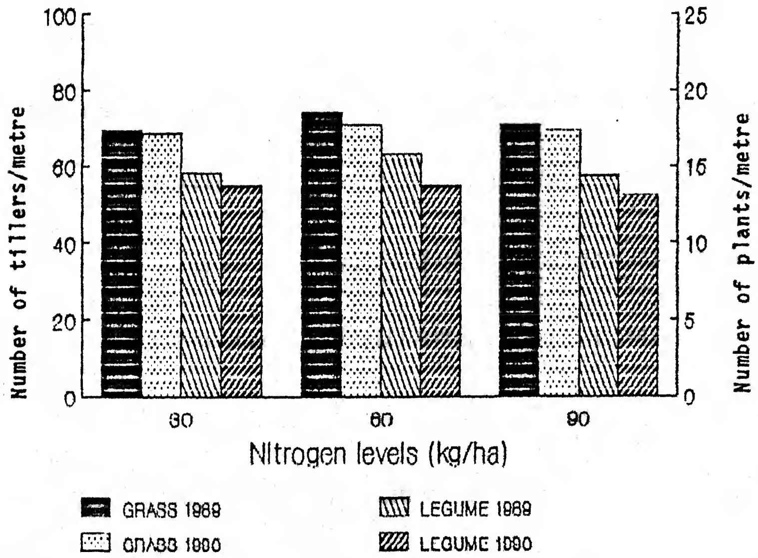
Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	61.4	16.2	61.4	13.6	61.4	14.9
IGFRI-S-4-2-1 (Bundel-2)	67.1	15.1	69.9	13.8	68.5	14.5
IGFRI-3808	86.2	13.6	78.0	13.1	82.1	13.4
SEm$\pm$	2.59		3.34			
CD at 5%	7.61		9.79			
Crop stands						
Pennisetum pedicellatum pure	85.3		83.8		84.6	
Pennisetum pedicellatum + cowpea	55.5	9.3	50.1	8.0	52.8	8.7
Pennisetum pedicellatum + clusterbean	73.8	20.6	75.3	18.8	74.6	19.7
SEm$\pm$	2.59		3.34			
CD at 5%	7.61		9.79			
Nitrogen levels (kg/ha)						
30	69.6	14.6	68.7	13.7	69.2	14.2
60	74.1	15.9	71.0	13.7	72.6	14.8
90	71.0	14.4	69.6	13.1	70.3	13.8
SEm$\pm$	2.59		3.34			
CD at 5%	NS		NS			
General mean	71.6	14.9	69.8	13.5		

NS = Not-significant

FIG 3: NUMBER OF TILLERS/PLANTS PER RUNNING METRE







Differential crop stands caused significant variation in number of tillers in both the years. The pure stand of *Pennisetum pedicellatum* recorded significantly higher number of tillers than its association with cowpea in both the years. In association of clusterbean, *Pennisetum pedicellatum*, however, showed significantly more number of tillers in 1989 whereas in 1990 the variation did not reach the level of significance. The plant population of clusterbean was 2 to 2.5 times greater than cowpea in intercropping system.

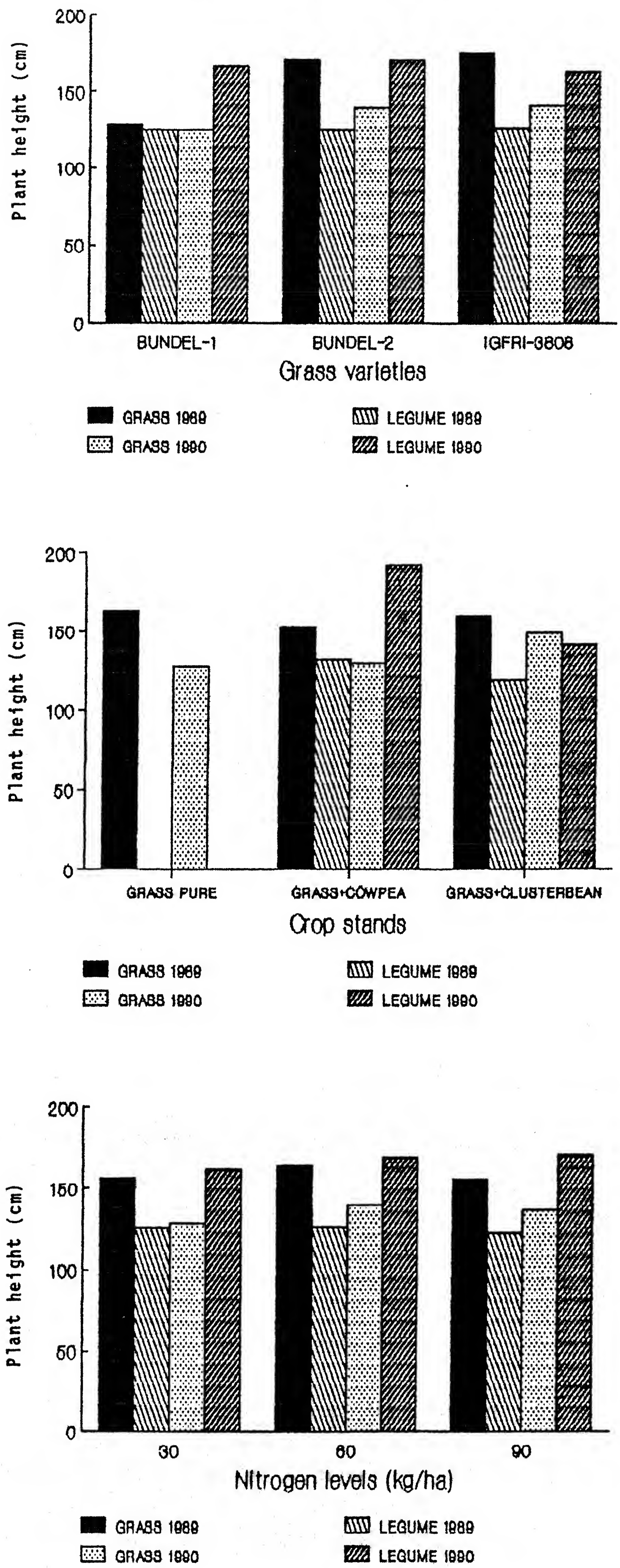
Significant difference in number of tillers was not observed due to increased levels of nitrogen from 30 to 90 kg/ha. However, 60 kg N/ha produced maximum number of tillers in *Pennisetum pedicellatum* as well as number of legume plants per running metre in both the years.

Plant height:. The data on plant height have been presented in Table 4 and depicted in Fig. 4. A perusal of the data revealed that *Pennisetum pedicellatum* attained more plant height (158.1 cm) in 1989 than in 1990 (135.1 cm). On the contrary, the mean plant height of legume component was higher in 1990 (166.9 cm) than in 1989 (125.1 cm). Significant variation in plant height of different *Pennisetum pedicellatum* varieties occurred and variety IGFRI-3808 though at par with Bundel-2 excelled over Bundel-1 in both the years. Further, Bundel-2 also established its significant superiority over Bundel-1 in plant height. The average plant height was maximum in case of IGFRI-3808 followed

Table 4. Plant height (cm) at harvesting stage

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	127.9	124.3	124.6	166.1	126.3	145.2
IGFRI-S-4-2-1 (Bundel-2)	171.0	124.9	139.7	171.0	155.4	147.9
IGFRI-3808	175.4	126.0	141.1	163.6	158.3	144.8
SEm±	3.51		3.01			
CD at 5%	10.31		8.83			
Crop stands						
Pennisetum pedicellatum pure	162.3		127.6		145.0	
Pennisetum pedicellatum + cowpea	152.9	131.5	129.3	192.4	141.1	162.0
Pennisetum pedicellatum + clusterbean	159.2	118.6	148.5	141.4	153.9	130.0
SEm±	3.51		3.01			
CD at 5%	NS		8.83			
Nitrogen levels (kg/ha)						
30	155.7	126.0	128.6	161.2	142.2	143.6
60	163.7	126.6	140.0	168.8	151.9	147.7
90	155.4	122.6	136.8	170.6	146.1	146.6
SEm±	3.51		3.01			
CD at 5%	NS		8.83			
General mean	158.1	125.1	135.1	166.9		

FIG 4: PLANT HEIGHT (cm)



by Bundel-2. Legumes attained maximum plant height in association with grass variety IGFRI-3808 in 1989 and with Bundel-2 in 1990. On an average, the plant height of legume varied in narrow range of 144.8 to 147.9 cm in association with different grass varieties.

The variation in plant height of *Pennisetum pedicellatum* under different crop stands was not significant in 1989. In 1990, however, *Pennisetum pedicellatum* registered significantly highest plant height in association with clusterbean as compared to either pure grass or its intercropping with cowpea which were at par between themselves. On an average, tallest grass plants were observed when intercropped with clusterbean. Between legumes, cowpea had taller plants than clusterbean in individual year as also over the years.

The levels of nitrogen did not influence plant height of grass components significantly in 1989. However, in 1990, *Pennisetum pedicellatum* had significantly tallest plants with 60 kg N/ha as compared to 30 kg N/ha. But both these levels did not differ statistically from 90 kg N/ha in terms of plant height. The trend in plant height of legume component was different in two years. Application of 90 kg N/ha showed slightly depressing effect on plant height in 1989 but favourable effect in 1990. The mean plant height was maximum at 60 kg N/ha.

The interaction varieties x crop stands for plant height was significant in both the years(Table 5). Variety Bundel-2 intercropped with cowpea produced tallest plant (184.7 cm) in

Table 5. Effect of crop stands X *Pennisetum pedicellatum* varieties on plant height (cm) of the grass component

Crop stands	1989			1990		
	Varieties			Varieties		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
Pennisetum pedicellatum pure	136.7	171.0	179.2	110.2	140.5	132.1
Pennisetum pedicellatum + cowpea	115.6	184.7	158.3	122.3	125.2	140.3
Pennisetum pedicellatum + clusterbean	131.4	170.6	175.6	141.3	153.5	150.9
SEm±	6.09			5.21		
CD at 5%	17.86			15.30		

1989 but did not differ significantly in pure stand or intercropped with clusterbean. Variety IGFRI-3808 in pure stand or intercropped with clusterbean also produced similar plant height. In 1990 also, variety Bundel-2 produced tallest plants when intercropped with clusterbean. However, this combination was at par with most of the interactions involving varieties x crop stands.

The significant interaction between crop stands and nitrogen levels in 1989 (Table 6) indicated that *Pennisetum pedicellatum* attained maximum plant height (170.2 cm) at 60 kg N/ha when intercropped with clusterbean closely followed by pure grass stand receiving 90 kg N/ha or grass in association with cowpea at 60 kg N/ha.

In 1990, *Pennisetum pedicellatum* varieties interacted significantly with nitrogen levels with the result that Bundel-2 recorded maximum plant height (148.9 cm) at 90 kg N/ha. This in turn did not differ statistically from its own plant height at 60 kg N/ha and the plant height of IGFRI-3808 receiving 30-90 kg N/ha.

The significant nitrogen x variety x crop stand interaction (Table 7) showed that the highest plant height (193.5 cm) occurred with variety IGFRI-3808 in pure stand fertilized with 60 kg N/ha. This combination was, however, at par with its intercropping by cowpea at same level of nitrogen and with Bundel-2 intercropped with clusterbean at 30 kg N/ha.

Table 6. Effect of nitrogen levels X crop stands and nitrogen levels X *Pennisetum pedicellatum* varieties on plant height (cm) of grass component

Nitrogen levels (kg/ha)	1989 Crop stands			1990 Varieties		
	Pennisetum pedicellatum pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
30	163.9	155.8	146.1	124.2	123.4	138.2
60	156.6	164.4	170.2	130.4	146.8	142.7
90	166.4	138.5	161.2	119.2	148.9	142.4
SEm±	6.09			5.21		
CD 5%	17.86			15.30		

Table 7. Effect of crop stands X *Pennisetum pedicellatum* varieties X nitrogen levels on plant height (cm) of grass component in 1989

Crop stands	varieties								
	IGFRI-S-43-1			IGFRI-S-4-2-1			IGFRI-3808		
	Nitrogen (kg/ha)								
	30	60	90	30	60	90	30	60	90
Pennisetum pedicellatum pure	148.9	119.3	141.9	172.0	145.5	176.5	170.8	193.5	173.5
Pennisetum pedicellatum + cowpea	128.3	140.1	78.5	176.4	166.2	182.6	174.0	187.0	171.9
Pennisetum pedicellatum + clusterbean	88.3	156.2	149.6	189.1	163.3	167.7	168.1	173.7	166.4
SEm±	26.7								
CD at 5%	78.3								

Number of functional leaves: The data on number of functional leaves per tiller (shoot) in case of *Pennisetum pedicellatum* and per plant in case of legumes have been presented in Table 8 and depicted in Fig. 5.

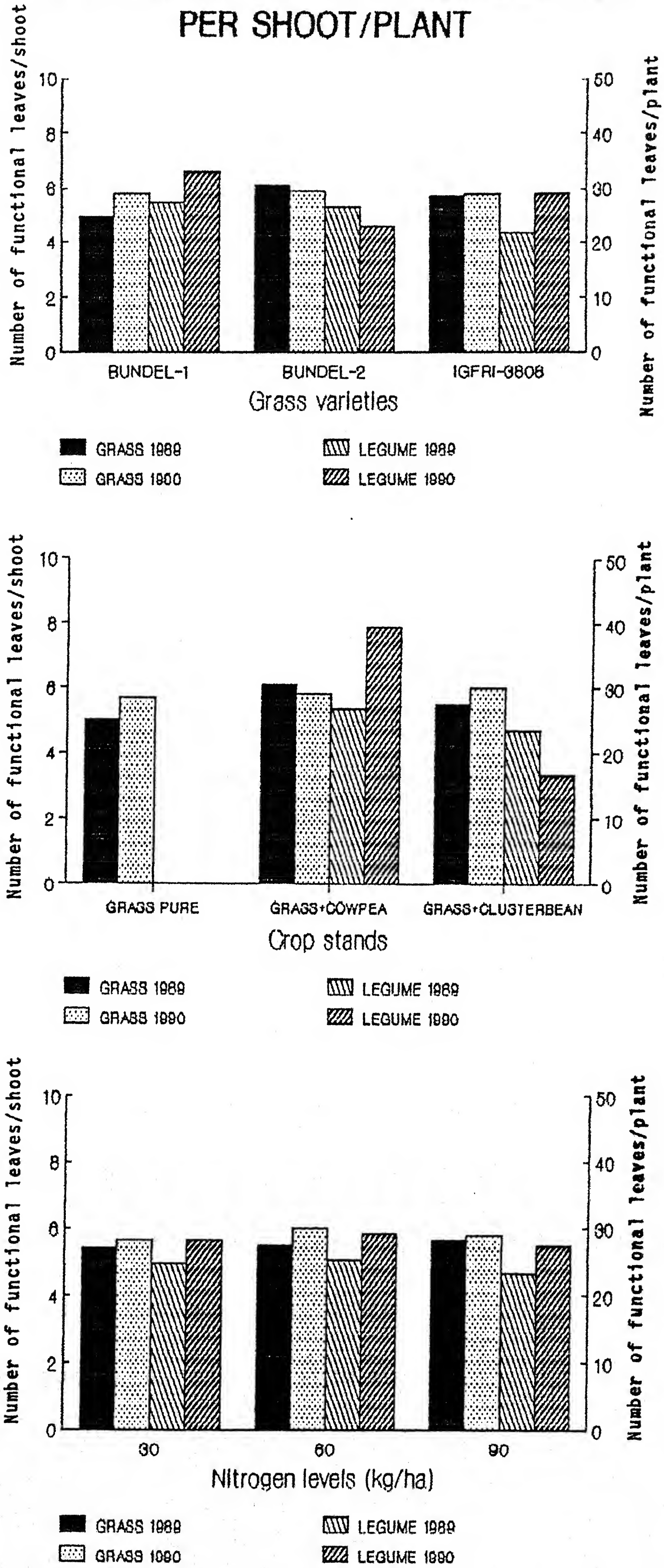
It is evident from the data that number of functional leaves in grass per tiller (5.8) and per plant in legumes (28.4) were more in 1990 than in 1989. *Pennisetum pedicellatum* varieties showed significant variation in number of functional leaves in 1989 only with the result that Bundel-2 and IGFRI-3808 were at par between themselves but significantly superior to Bundel-1. In 1990, *Pennisetum pedicellatum* varieties produced almost similar number of leaves per tiller and differences were not significant. Average number of leaves were more in Bundel-2 followed by IGFRI-3808 and Bundel-1. Number of functional leaves per plant in legumes was maximum in association with Bundel-1 in both the years and same was the case with respect to average data over the years.

Pure stand of *Pennisetum pedicellatum* produced lesser number of leaves per tiller as compared to its association with cowpea or clusterbean in both the years. In 1989, *Pennisetum pedicellatum* in association with cowpea had significantly more number of leaves than pure grass. But grass in association with cowpea or clusterbean did not differ significantly between themselves. However, in 1990, the differences in number of grass leaves due to crop stands were not significant.

Table 8. Number of functional leaves per shoot/plant

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	4.9	27.3	5.8	33.0	5.4	30.2
IGFRI-S-4-2-1 (Bundel-2)	6.1	26.5	5.9	23.1	6.0	24.8
IGFRI-3808	5.7	22.0	5.8	29.1	5.8	28.1
SEm±	0.30		0.11			
CD at 5%	0.9		NS			
Crop stands						
Pennisetum pedicellatum pure	5.0		5.7		5.1	
Pennisetum pedicellatum + cowpea	6.1	26.8	5.8	39.5	6.0	33.2
Pennisetum pedicellatum + clusterbean	5.5	23.4	6.0	16.8	5.8	20.1
SEm±	0.30		0.11			
CD at 5%	0.9		NS			
Nitrogen levels (kg/ha)						
30	5.4	24.9	5.7	28.4	5.6	26.7
60	5.5	25.3	6.0	29.3	5.8	27.3
90	5.7	23.2	5.8	27.4	5.8	25.3
SEm±	0.30		0.11			
CD at 5%	NS		NS			
General mean	5.5	25.1	5.8	28.4		

FIG 5: NUMBER OF FUNCTIONAL LEAVES PER SHOOT/PLANT



Increasing levels of nitrogen did not bring significant variation in number of leaves per tiller in grass, with the result that practically equal number of leaves were produced with 30 to 90 kg N/ha.

Leaf area index (LAI): The data on leaf area index have been presented in Table 9 and depicted in Fig.6. The leaf area index of the sward was 19.4 in 1990 against 8.3 in 1989. Grass varieties did not differ significantly in leaf areas index in 1989 but significant variation was observed in 1990. In 1989, variety IGFRI-3808 produced highest LAI. In 1990, variety IGFRI-3808 produced significantly higher LAI over Bundel-2 which in turn did not differ significantly from Bundel-1. The data averaged over the years indicated higher LAI with IGFRI-3808 followed by Bundel-2.

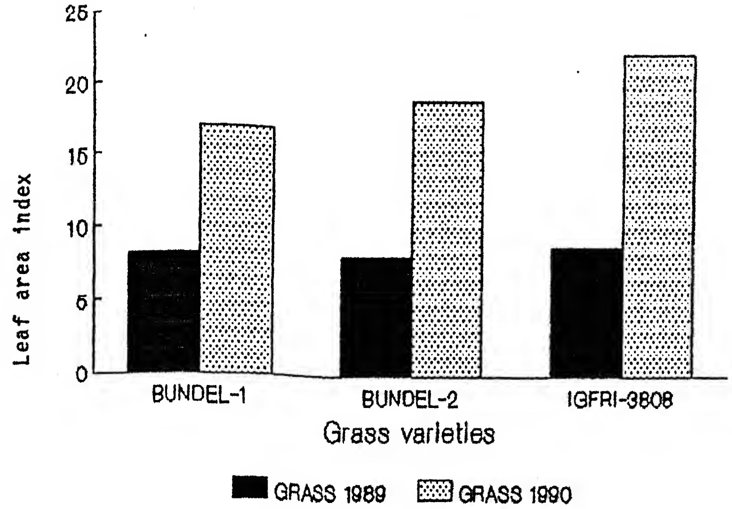
Differential crop stands did not cause significant variation in leaf area index in 1989. Whereas, in 1990 grass grown pure or in association with clusterbean resulted in statistically similar LAI but significantly greater than sward consisting of grass + cowpea. Average data over the years showed highest LAI with grass + legumes followed by pure grass.

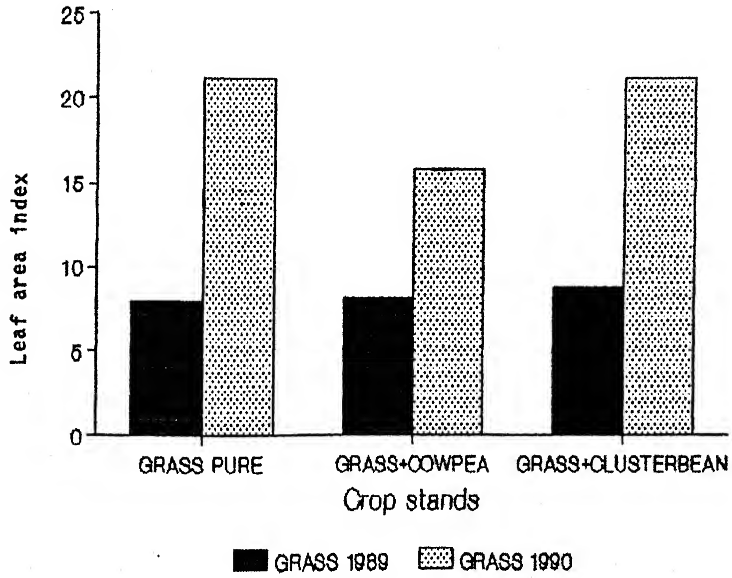
Nitrogen nutrition did not show significant variation in leaf area index in both the years. However, highest leaf area index was recorded at 60 kg N/ha in 1989 and at 90 kg N/ha in 1990. The data averaged over the years also indicated the highest leaf area index at 60 kg N/ha.

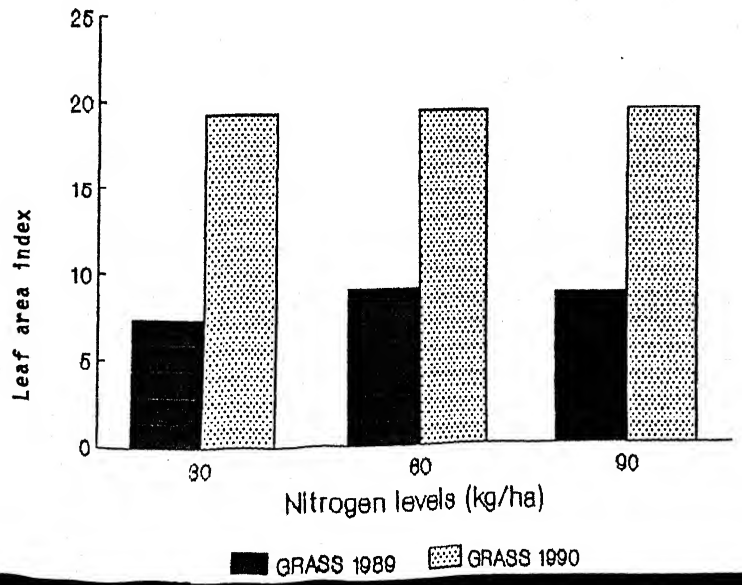
Table 9. Leaf area index of grass + legume (Sward)

Treatments	1989	1990	Mean
Pennisetum pedicellatum varieties			
IGFRI-S-43-1 (Bundel-1)	8.1	16.8	12.5
IGFRI-S-4-2-1 (Bundel-2)	8.1	19.0	13.6
IGFRI-3808	8.9	22.4	15.7
SEm±	0.90	0.84	
CD at 5%	NS	2.5	
Crop stands			
Pennisetum pedicellatum pure	7.9	21.1	14.5
Pennisetum pedicellatum + cowpea	8.2	15.8	12.0
Pennisetum pedicellatum + clusterbean	8.9	21.3	15.1
SEm±	0.90	0.84	
CD at 5%	NS	2.5	
Nitrogen levels (kg/ha)			
30	7.3	19.3	13.3
60	9.0	19.4	14.2
90	8.7	19.5	14.1
SEm±	0.90	0.84	
CD at 5%	NS	NS	
General mean	8.3	19.4	

FIG 6: LEAF AREA INDEX OF GRASS + LEGUME (SWARD)







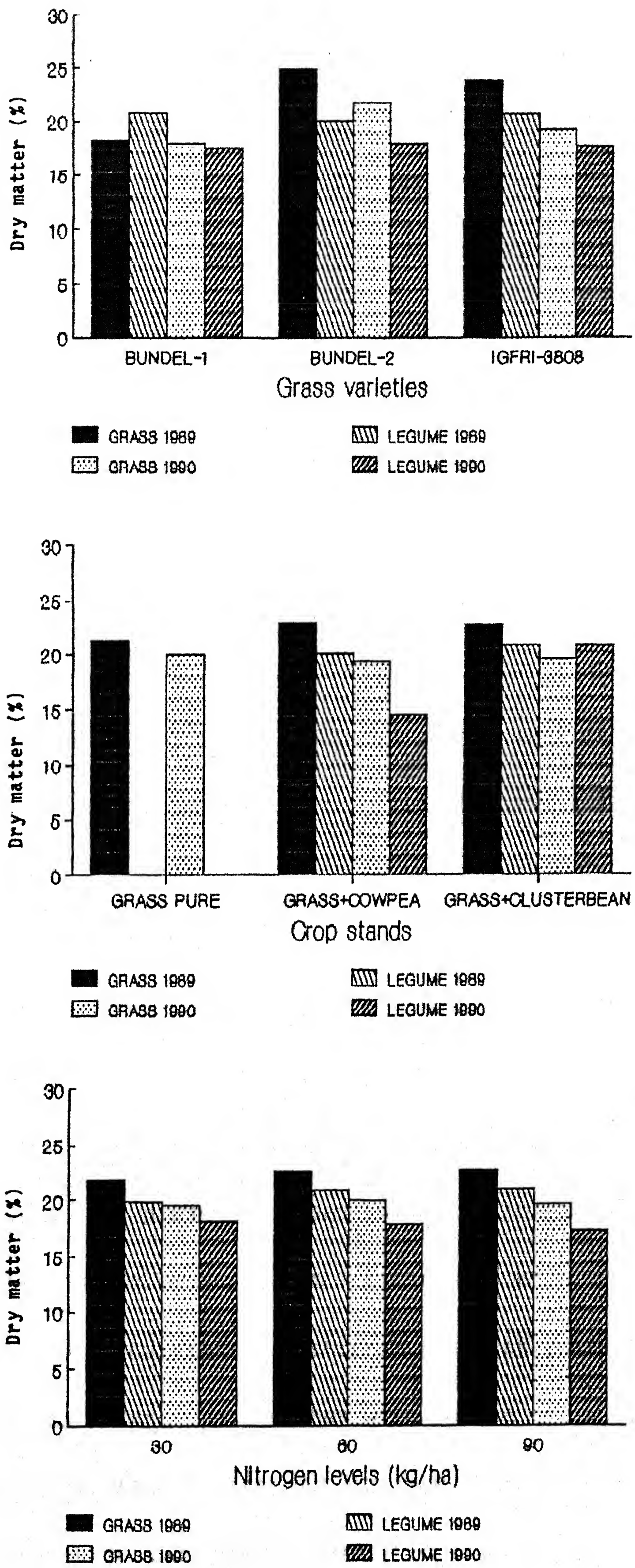
Dry matter content (%): The perusal of the data on dry matter content (Table 10 and Fig. 7) showed that the average dry matter content of *Pennisetum pedicellatum* at harvest was 22.3 per cent in 1989 and 19.7 per cent in 1990. In both the years, grass varieties differed significantly in dry matter content. In 1989, variety Bundel-2 and IGFRI-3808 accumulated significantly higher dry matter content as compared to Bundel-1. In 1990, also Bundel-2 accumulated significantly higher dry matter content (21.8 per cent) than IGFRI-3808 and Bundel-1 which did not show significant variation between themselves. On an average over the years, variety Bundel-2 showed highest dry matter content followed by IGFRI-3808 and Bundel-1. The dry matter content of legume component was also greater in 1989 (20.6 %) than in 1990 (17.7 %). The association of legume with different grass varieties did not cause tangible variation in its dry matter content in both the years.

In 1989, *Pennisetum pedicellatum* grown with cowpea or clusterbean exhibited statistically similar dry matter content but greater than grass grown pure. In 1990, on the other hand, grass grown as pure stand gave relatively higher dry matter content than that in mixed stand. However, the differences were not significant. On an average, grass in association with cowpea or clusterbean gave 0.5 % unit more dry matter than the grass in pure stand. Clusterbean recorded greater dry matter content than cowpea in both the years.

Table 10. Dry matter content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	18.2	20.8	17.9	17.5	18.1	19.2
IGFRI-S-4-2-1 (Bundel-2)	24.9	20.1	21.8	17.9	23.4	19.0
IGFRI-3808	23.9	20.7	19.2	17.7	21.6	19.2
SEm±	0.39		0.46			
CD at 5%	1.1		1.4			
Crop stands						
Pennisetum pedicellatum pure	21.3		20.0		20.7	
Pennisetum pedicellatum + cowpea	23.0	20.1	19.4	14.6	21.2	17.4
Pennisetum pedicellatum + clusterbean	22.8	20.9	19.6	20.9	21.2	20.9
SEm±	0.39		0.46			
CD at 5%	1.1		NS			
Nitrogen levels (kg/ha)						
30	21.8	19.8	19.5	18.1	20.7	19.0
60	22.5	20.9	19.9	17.8	21.2	19.4
90	22.7	21.0	19.6	17.2	21.2	19.1
SEm±	0.39		0.46			
CD at 5%	NS		NS			
General mean	22.3	20.5	19.7	17.7		

FIG 7: DRY MATTER CONTENT



Nitrogen levels did not influence the dry matter content significantly in any of the years. However, there was marginal increase in dry matter content with increasing nitrogen levels up to 60 kg N/ha. Thereafter, it remained practically constant. In case of legumes, the dry matter content increased in 1989 and decreased in 1990 with increase in nitrogen doses.

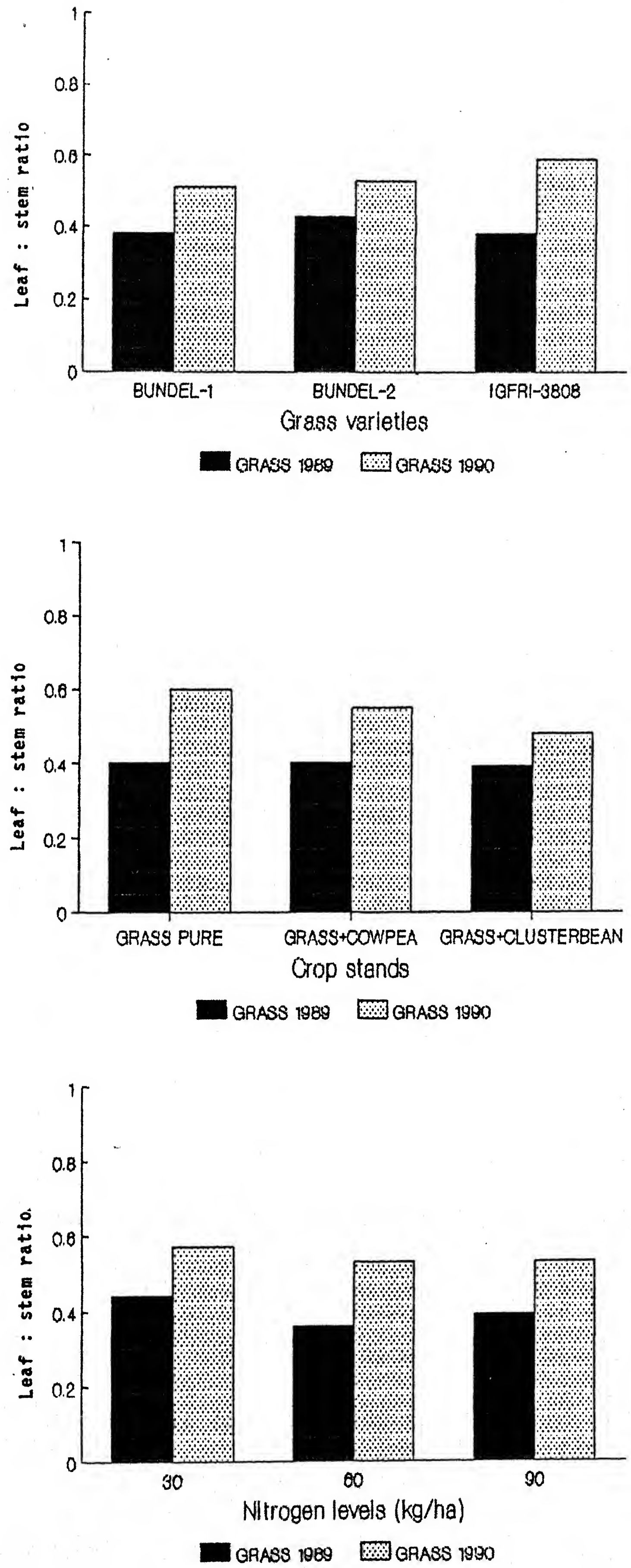
Leaf:stem ratio: The data on leaf:stem ratio of grass component have been presented in Table 11 and depicted in Fig. 8. *Pennisetum pedicellatum* gave higher leaf:stem ratio in 1990 (0.54) than in 1989 (0.40). The leaf:stem ratio of different varieties of *Pennisetum pedicellatum* did not differ significantly in 1989, however, variety Bundel-2 gave higher leaf:stem ratio than Bundel-1 and IGFRI-3808 which resulted in similar leaf:stem ratio. In 1990, the leaf:stem ratio of variety IGFRI-3808 was significantly greater than Bundel-1 but at par with Bundel-2. The latter two varieties were also at par between themselves. The data averaged over the years showed that variety IGFRI-3808 gave maximum leaf:stem ratio followed by Bundel-2 and Bundel-1.

Pure stand of grass produced highest leaf:stem ratio followed by *Pennisetum pedicellatum* intercropped with cowpea and clusterbean in both the years. Leaf:stem ratio of grass in pure stand as well as intercropped either with cowpea or clusterbean did not record significant variation in 1989. However, in 1990, grass in pure stand and intercropped with cowpea were at par between themselves but significantly superior to that intercropped with clusterbean. On an average, the order of

Table 11. Leaf:stem ratio

Treatments	1989	1990	Mean
	Grass	Grass	Grass
Pennisetum pedicellatum varieties			
IGFRI-S-43-1 (Bundel-1)	0.38	0.51	0.45
IGFRI-S-4-2-1 (Bundel-2)	0.43	0.53	0.48
IGFRI-3808	0.38	0.59	0.49
SEm±	0.02	0.02	
CD at 5%	NS	0.06	
Crop stands			
Pennisetum pedicellatum pure	0.40	0.60	0.50
Pennisetum pedicellatum + cowpea	0.40	0.55	0.48
Pennisetum pedicellatum + clusterbean	0.39	0.48	0.44
SEm±	0.02	0.02	
CD at 5%	NS	0.06	
Nitrogen levels (kg/ha)			
30	0.44	0.57	0.51
60	0.36	0.53	0.45
90	0.39	0.53	0.46
SEm±	0.02	0.02	
CD at 5%	0.07	NS	
General mean	0.40	0.54	

FIG 8: LEAF:STEM RATIO



leaf:stem ratio was grass in pure stand > intercropped with cowpea > intercropped with clusterbean.

Nitrogen nutrition exercised significant variation in leaf:stem ratio in 1989 only. The leaf:stem ratio was highest at 30 kg N/ha in both the years. Application of 60 and 90 N/ha showed similar leaf:stem ratio.

The interaction, crop stands x nitrogen levels (Table 12) significantly influenced the leaf:stem ratio with the result that *Pennisetum pedicellatum* intercropped with cowpea receiving 30 kg N/ha produced highest leaf:stem ratio (0.52) followed by grass grown in pure stand fertilized with 90 kg N/ha (0.45).

Relative leaf turgidity percentage: The data on percentage relative leaf turgidity or relative water content of grass and legume components have been presented in Table 13 and depicted in Fig. 9.

The average relative leaf turgidity of *Pennisetum pedicellatum* was very low ? 67.3 % in 1989 against 96.3 % in 1990. Similarly, the relative leaf turgidity of legume for corresponding years was 86.3 and 96.1 per cent. Grass did not show significant variation in relative leaf turgidity due to treatment variables in both the years. Variety Bundel-1 exhibited maximum relative leaf turgidity followed by Bundel-2 consistently. However, the relative leaf turgidity of legumes was maximum when grown in association with IGFRI-3808 in both the years. Dinanath grass showed maximum relative water content when

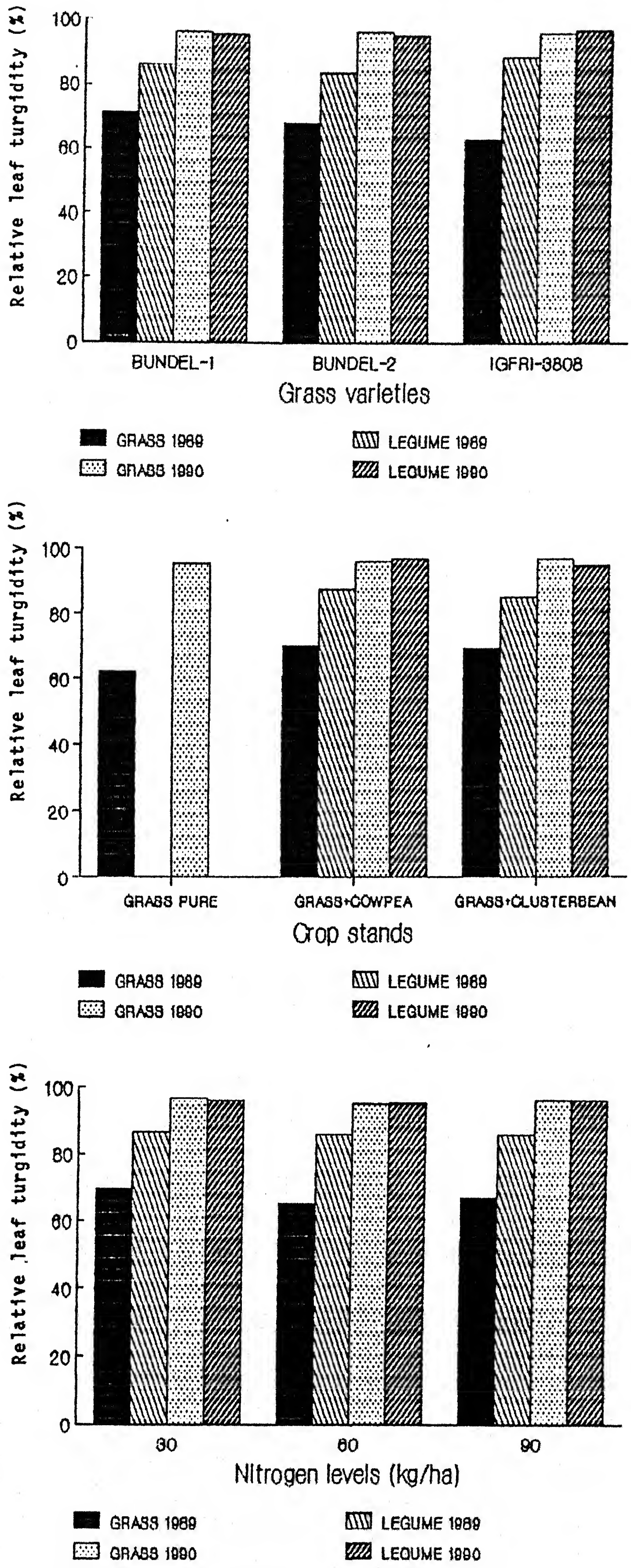
Table 12. Effect of crop stands X nitrogen levels on leaf:stem ratio of grass component

Crop stands	1989		
	Nitrogen levels (kg/ha)		
	30	60	90
Pennisetum pedicellatum pure	0.38	0.38	0.45
Pennisetum pedicellatum + cowpea	0.52	0.32	0.37
Pennisetum pedicellatum + clusterbean	0.42	0.38	0.35
SEm±	0.04		
CD at 5%	0.12		

Table 13. Relative leaf turgidity (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	70.9	86.1	96.2	95.8	83.6	91.0
IGFRI-S-4-2-1 (Bundel-2)	68.1	83.9	96.7	95.5	82.4	89.7
IGFRI-3808	62.9	88.7	96.1	96.8	79.5	92.8
SEm±	3.17		0.51			
CD at 5%	NS		NS			
Crop stands						
Pennisetum pedicellatum pure	62.5		95.6		79.1	
Pennisetum pedicellatum + cowpea	70.1	87.4	96.1	97.2	83.1	92.3
Pennisetum pedicellatum + clusterbean	69.4	85.1	97.3	94.9	83.4	90.0
SEm±	3.17		0.51			
CD at 5%	NS		NS			
Nitrogen levels (kg/ha)						
30	69.7	86.7	96.9	96.2	83.3	91.5
60	65.2	86.0	95.4	95.7	80.3	90.9
90	67.0	86.1	96.7	96.5	81.9	91.3
SEm±	3.17		0.51			
CD at 5%	NS		NS			
General mean	67.3	86.3	96.3	96.1		

FIG 9: RELATIVE LEAF TURGIDITY



intercropped with cowpea in 1989 and with clusterbean in 1990. On an average, *Pennisetum pedicellatum* exhibited similar relative water content intercropped either with cowpea or clusterbean but greater than pure stand of grass. Between legumes, cowpea recorded 2.3 per cent units more relative water content than clusterbean in both the years.

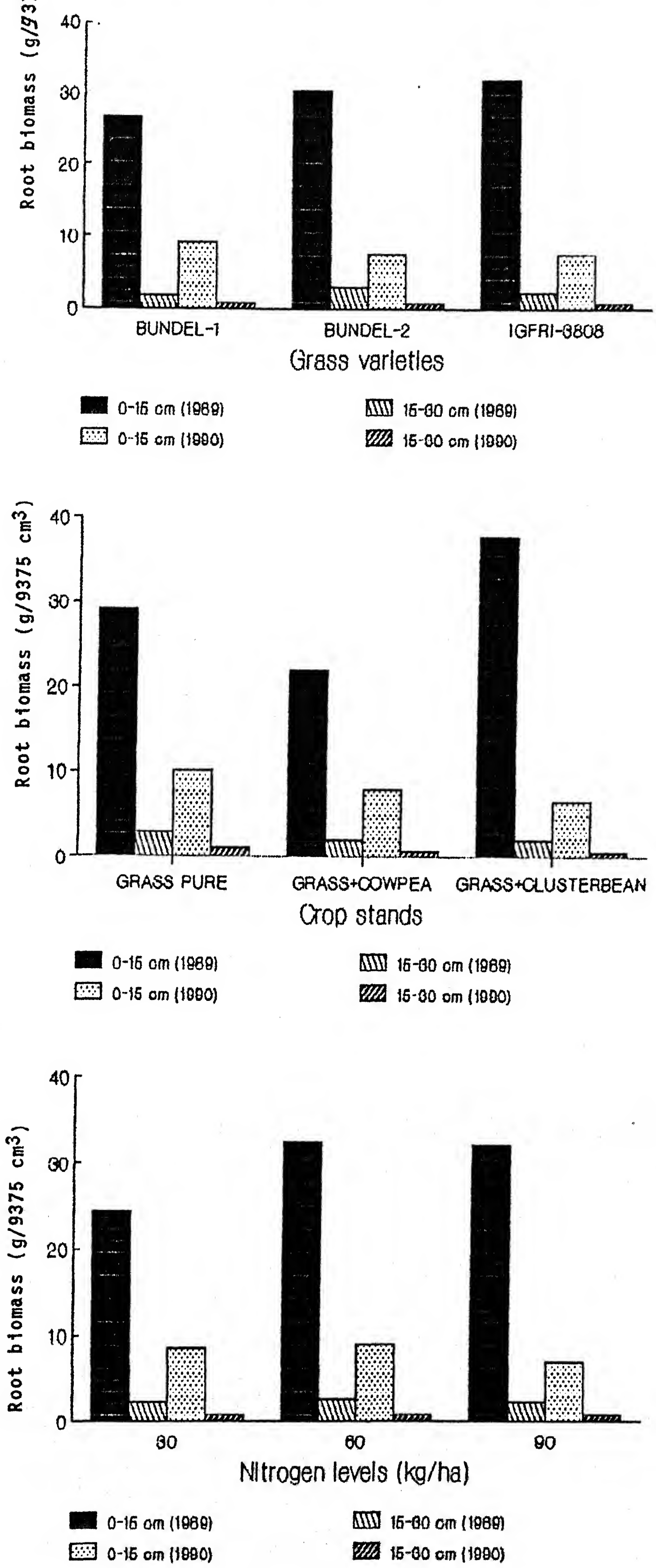
Application of 30 kg N/ha showed highest relative leaf turgidity percentage in 1989. In 1990, the relative water content remained similar at 30 and 90 kg N/ha. However, the average data showed higher relative leaf turgidity with 30 kg N/ha. In case of legumes also, lower dose of 30 kg N/ha tended to give marginally higher relative water content than higher doses.

Root biomass of *Pennisetum pedicellatum*: The data on root biomass of grass component in terms of dry weight have been presented in Table 14 and depicted in Fig. 10. In 1989, the accumulation of root biomass in 0-15 cm was 3.6 and in 15-30 cm depth, 3 times more than that in 1990. Thus, up to 30 cm depth, the total root mass in 1989 was more than 3 times to that of 1990. None of the treatment variables influenced the root biomass significantly in both the years. In 1989, variety IGFRI-3808 accumulated maximum root biomass followed by Bundel-2 in 0-15 cm depth. In 15-30 cm depth, however, Bundel-2 had an edge over IGFRI-3808. The accumulation of total root biomass in 0-30 cm depth was maximum in IGFRI-3808 closely followed by Bundel-2. In 1990, Bundel-1 accumulated maximum root biomass in 0-15 cm depth. Bundel-2 and

Table 14. Root biomass (dry weight g/9375 cm^3) of *Pennisetum pedicellatum* in different layers

Treatments	1989			1990		
	0-15 (cm)	15-30 (cm)	0-30 (cm)	0-15 (cm)	15-30 (cm)	0-30 (cm)
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	26.5	1.8	28.3	9.1	0.8	9.9
IGFRI-S-4-2-1 (Bundel-2)	30.5	2.9	33.4	7.6	0.8	8.4
IGFRI-3808	31.9	2.3	34.2	7.5	0.7	8.2
SEm$\pm$	4.49	0.33	4.41	1.29	0.17	1.28
CD at 5%	NS	NS	NS	NS	NS	NS
Crop stands						
Pennisetum pedicellatum pure	29.1	3.0	32.1	10.1	1.0	11.1
Pennisetum pedicellatum + cowpea	22.0	2.0	24.0	7.9	0.7	8.6
Pennisetum pedicellatum + clusterbean	37.8	2.0	39.8	6.5	0.6	7.1
SEm$\pm$	4.49	0.33	4.41	1.29	0.17	1.28
CD at 5%	NS	NS	NS	NS	NS	NS
Nitrogen levels (kg/ha)						
30	24.3	2.2	26.5	8.5	0.8	9.3
60	32.4	2.6	35.0	9.0	0.7	9.7
90	32.1	2.2	34.3	6.9	0.7	7.6
SEm$\pm$	4.49	0.33	4.41	1.29	0.17	1.28
CD at 5%	NS	NS	NS	NS	NS	NS
General mean	29.6	2.2	32.0	8.1	0.7	8.9

FIG 10: ROOT BIOMASS OF *Pennisetum pedicellatum* IN DIFFERENT SOIL LAYERS



IGFRI-3808 accumulated almost similar root biomass. In 15-30 cm depth the accumulation of root biomass was practically the same in all the grass varieties. The total dry weight of roots in 0-30 cm depth did not differ significantly in both the years. In 1989, total dry weight of roots was highest with variety IGFRI-3808 whereas in 1990, variety Bundel-1 produced maximum total dry root followed by Bundel-2 in both the years.

In 1989, *Pennisetum pedicellatum* in association with clusterbean accumulated highest root mass in 0-15 cm whereas in 15-30 cm depth the maximum biomass was observed in pure grass stand. In 1990, the pure stand of grass exhibited maximum root biomass accumulation followed by grass in association with cowpea.

In so far as the total root dry weight up to 30 cm depth was concerned, grass in association with clusterbean accumulated maximum root biomass in 1989 whereas in 1990 it was maximum when grass was grown in pure stand. However, varying crop stands did not differ significantly in total dry weight of root biomass of grass component.

Increasing levels of nitrogen up to 60 kg N/ha increased the root biomass in both the depths in 1989 and in 0-15 cm depth in 1990. However, total root biomass accumulation in 0-30 cm depth increased up to 60 kg N/ha and further increase in nitrogen dose to 90 kg/ha did not reflect favourable effect.

The interaction, *Pennisetum pedicellatum* varieties x nitrogen levels (Table 15) showed significant effect on

Table 15. Effect of nitrogen levels X *Pennisetum pedicellatum* varieties on root biomass (g/9375 cm^3) of grass components in 15-30 cm layer in 1990

Nitrogen levels (kg/ha)	Varieties		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
30	1.3	3.0	2.3
60	2.0	4.3	1.5
90	2.0	1.5	3.0
SEm+	0.57		
CD at 5%	1.9		

accumulation of root biomass in 15-30 cm depth in 1990. Variety Bundel-2 at 30 as well as 60 kg N/ha and IGFRI-3808 at 90 kg N/ha accumulated statistically similar root biomass but greater than other combinations.

Nodulation in forage legumes: Table 16 and Fig. 11 present the data on number of root nodules from 25 cm x 25 cm x 30 cm soil volume (18750 cm^3). The average nodulation count (319.2) was higher in 1989 than in 1990 (303.5). Legume intercropped with Bundel-1 recorded maximum nodulation count in both the years. Further, cowpea had 2.6 times more number of nodules in 1989 and 3.6 times more number of nodules in 1990 as compared to clusterbean.

Nitrogen nutrition up to 60 kg/ha increased the nodulation. Further increase in the level of nitrogen to 90 kg/ha, however, caused reduction in number of nodules. Nevertheless, the nodulation count at 90 kg N/ha remained higher than that at 30 kg N/ha.

Forage Yield:

The data on green forage and dry matter yields are presented in Table 17 and depicted in Fig. 12 and 13.

Green forage yield: The average green forage yield was higher in 1990 (455.2 q/ha) than in 1989 (334.8 q/ha). *Pennisetum pedicellatum* varieties did not differ significantly in total green forage yield (grass + legume) in both the years. In 1989,

Table 16. Number of nodules in legumes in 18750 cm^3

Treatments	1989	1990	Mean
Pennisetum pedicellatum varieties			
IGFRI-S-43-1 (Bundel-1)	399.8	365.2	382.5
IGFRI-S-4-2-1 (Bundel-2)	268.5	282.0	275.3
IGFRI-3808	289.3	263.3	276.3
Crop stands			
Pennisetum pedicellatum pure			
Pennisetum pedicellatum + cowpea	460.2	475.0	467.6
Pennisetum pedicellatum + clusterbean	178.2	131.9	155.1
Nitrogen levels (kg/ha)			
30	258.8	262.1	260.5
60	382.5	335.6	359.1
90	316.4	312.8	314.6
General mean	319.2	303.5	

FIG 11: NUMBER OF NODULES IN LEGUME

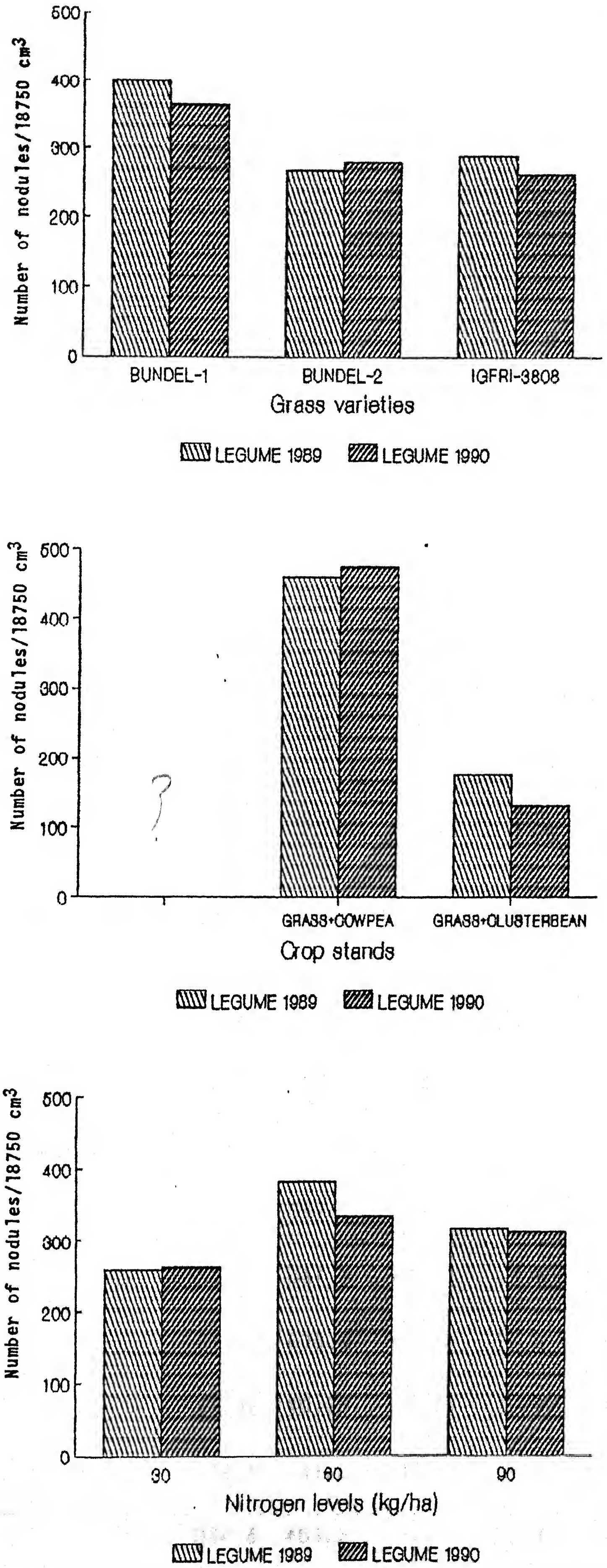
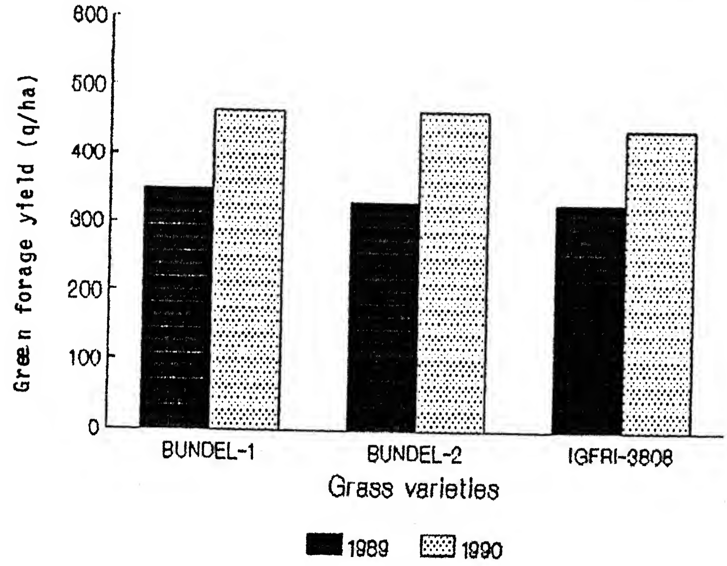
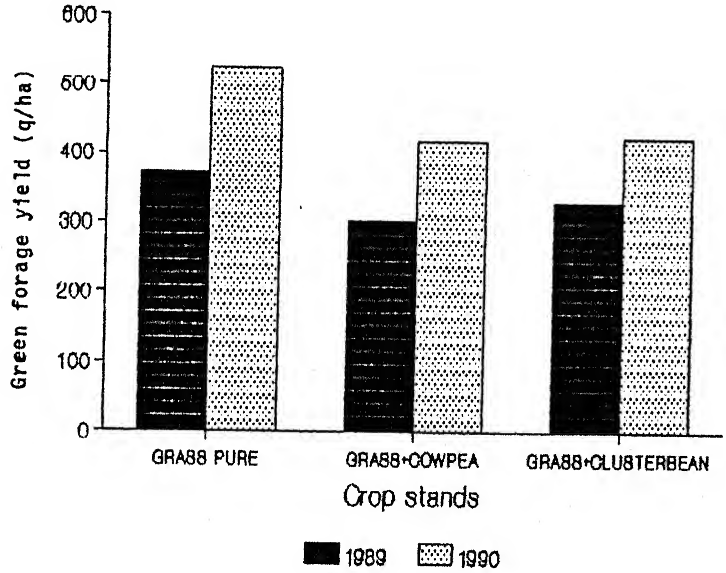


Table 17. Total green forage and dry matter yield (q/ha)

Treatments	Green forage yield			Dry matter yield		
	1989	1990	Pooled	1989	1990	Pooled
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	347.5	463.6	405.6	67.2	82.8	75.0
IGFRI-S-4-2-1 (Bundel-2)	328.8	464.1	396.5	77.7	97.5	87.6
IGFRI-3808	328.0	437.8	382.9	75.1	81.9	78.5
SEm±	11.80	10.75	9.13	2.49	3.04	2.09
CD at 5%	NS	NS	NS	7.3	8.9	5.9
Crop stands						
Pennisetum pedicellatum pure	371.7	523.0	447.4	81.0	105.0	93.0
Pennisetum pedicellatum + cowpea	302.7	418.6	360.7	65.2	72.8	69.0
Pennisetum pedicellatum + clusterbean	329.9	424.0	377.0	73.8	84.5	79.2
SEm±	11.80	10.75	9.13	2.49	3.04	2.09
CD at 5%	34.6	31.5	25.9	7.3	8.9	5.9
Nitrogen levels (kg/ha)						
30	315.5	391.5	353.5	66.6	75.2	70.9
60	334.8	467.3	401.1	75.6	90.2	82.9
90	354.1	506.9	430.1	77.8	97.0	87.4
SEm±	11.80	10.75	9.13	2.49	3.04	2.09
CD at 5%	34.6	31.5	25.9	7.3	8.9	5.9
General mean	334.8	455.2		73.3	87.4	

FIG 12: TOTAL GREEN FORAGE YIELD (q/ha)





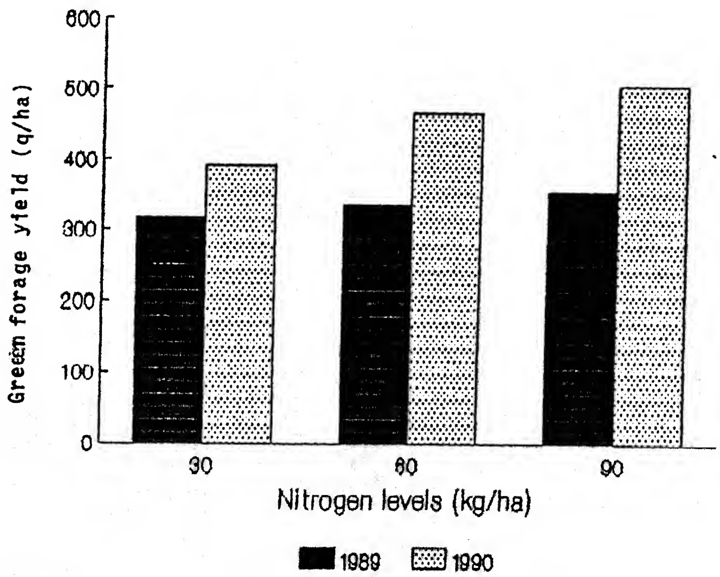
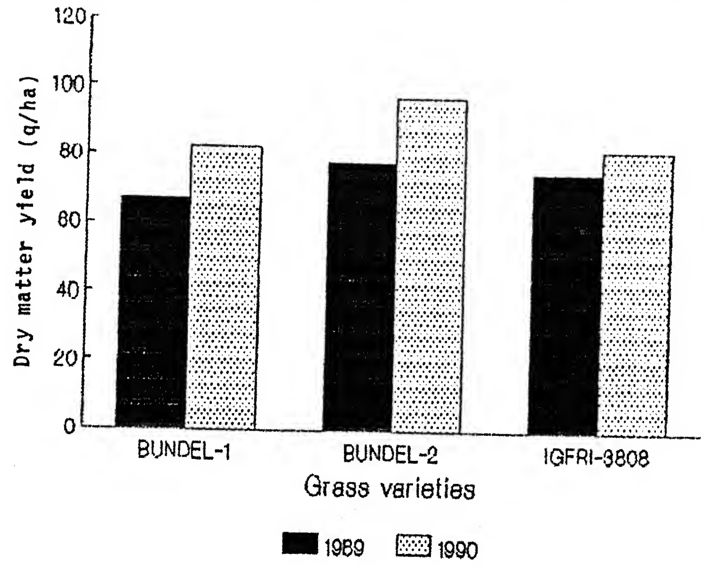
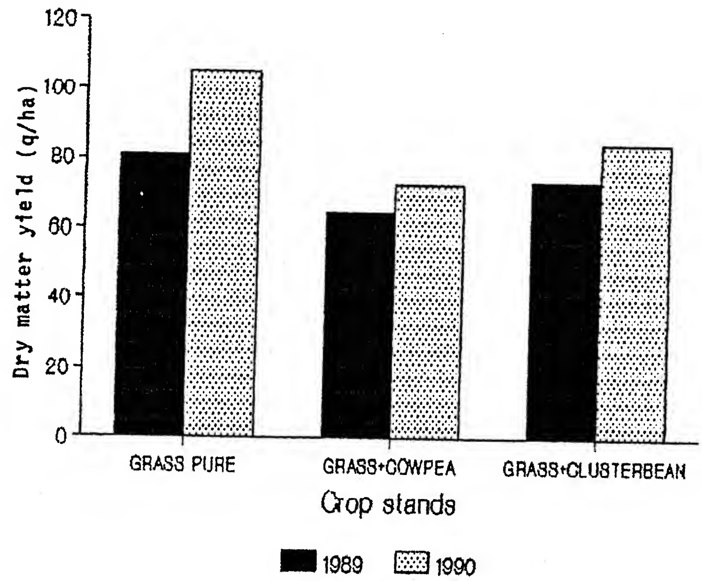
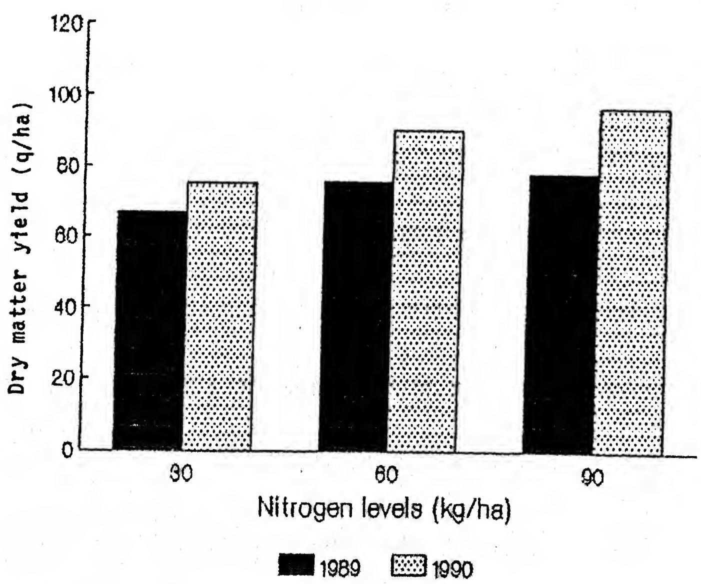


FIG 13: TOTAL DRY MATTER YIELD (q/ha)







however, variety Bundel-1 produced higher yield than Bundel-2 and IGFRI-3808 which gave similar yield levels. In 1990, variety Bundel-2 and Bundel-1 produced practically similar green forage yield but greater than IGFRI-3808. On the basis of pooled analysis, the varieties did not differ significantly in green forage yield. However, variety Bundel-1 produced highest green forage yield of 405.6 q/ha followed by Bundel-2 (396.5 q/ha).

Pennisetum pedicellatum in pure stand produced significantly higher green forage yield as compared to its intercropping with clusterbean or cowpea. Among intercropping systems, grass + clusterbean proved consistently superior over grass + cowpea. The pooled analysis also indicated similar trend.

Nitrogen nutrition at 90 kg N/ha significantly increased the green forage production as compared to 30 Kg N/ha in 1989 and as compared to 30 and 60 kg N/ha in 1990. The difference between 60 and 90 Kg N/ha was at par in 1989 but significantly different in 1990. Similarly, the green forage yields with 30 and 60 kg N/ha were at par in 1989 but significantly different in 1990. In 1990, significant linear increase in green forage yield was observed with increase in nitrogen from 30 to 90 kg N/ha. Significantly higher green forage yields were recorded due to increasing levels of nitrogen from 30 to 90 kg/ha on the basis of pooled analysis.

Dry matter yield: The data on dry matter yield are presented in Table 17 and shown in Fig. 13. The data revealed that the average dry matter yield was higher in 1990 (87.4 q/ha) than in 1989 (73.3 q/ha). There was significant variation in dry matter

yields of *Pennisetum pedicellatum* varieties in both the years. In 1989, variety Bundel-2 produced significantly higher dry matter yield over Bundel-1 but was at par with IGFRI-3808. In 1990 also variety Bundel-2 gave significant lead over Bundel-1 which in turn did not differ statistically from IGFRI-3808. On the basis of pooled analysis also, variety Bundel-2 (87.6 q/ha) significantly outyielded IGFRI-3808 (78.5 q/ha) and Bundel-1 (75.0 q/ha) in dry matter production which is at par between themselves.

Differential crop stands varied significantly in terms of dry matter yield in both the years. However, in 1989, pure grass stand gave significantly higher dry matter yield as compared to its intercropping with cowpea but was at par with grass + clusterbean intercropping. In 1990, pure stand of grass resulted in significantly higher dry matter yield than both the intercropping systems which also differed significantly from each other. Association of grass with clusterbean accumulated greater dry matter than its association with cowpea in both the years. Pooled analysis also indicated similar trend.

Increasing levels of nitrogen from 30 to 90 kg N/ha progressively increased the dry matter production in both the years. Application of 60 and 90 kg N/ha produced statistically similar dry matter yields but both these levels yielded significantly higher dry matter than 30 kg N/ha in both the years. Similar was the trend with respect to pooled analysis of the data.

Forage productivity per day: The data on green and dry matter productivity (q/ha/day) are presented in Table 18 and shown in Fig. 14 and 15. The average green forage productivity was 4.2 q/ha/day in 1989 against 5.4 q/ha/day in 1990. The corresponding levels of productivity in terms of dry matter were 0.9 and 1.0 q/ha/day.

Pennisetum pedicellatum varieties did not differ significantly in green forage productivity but recorded significant variation in dry matter productivity in both the years. Variety Bundel-1 gave maximum green forage productivity of 4.3 q/ha/day followed by Bundel-2 and IGFRI-3808 in 1989. But in 1990 , Bundel-2 and Bundel-1 showed maximum productivity of 5.5 q/ha/day followed by IGFRI-3808. The data averaged over the years also indicated that the productivity was in the order of Bundel-1 > Bundel-2 >IGFRI-3808. Variety Bundel-2 showed significantly greater dry matter productivity over Bundel-1 in 1989 but was at par with IGFRI-3808. In 1990, Bundel-2 registered significantly highest dry matter productivity over Bundel-1 and IGFRI-3808 which showed numerically similar dry matter productivity. The data averaged over the years also indicated that variety Bundel-2 is better than Bundel-1 and IGFRI-3808 in dry matter productivity.

Pure stand of *Pennisetum pedicellatum* exhibited significantly higher green forage productivity than its intercropping with cowpea and clusterbean in both the years. The values of green forage productivity of two intercropping systems

Table 18. Green forage and dry matter productivity (q/ha/day)

Treatments	Green forage			Dry matter		
	1989	1990	mean	1989	1990	mean
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	4.3	5.5	4.9	0.8	1.0	0.9
IGFRI-S-4-2-1 (Bundel-2)	4.1	5.5	4.8	1.0	1.2	1.1
IGFRI-3808	4.1	5.2	4.7	0.9	1.0	0.9
SEm±	0.15	0.12		0.03	0.04	
CD at 5%	NS	NS		0.1	0.1	
Crop stands						
Pennisetum pedicellatum pure	4.7	6.2	5.5	1.0	1.3	1.2
Pennisetum pedicellatum + cowpea	3.8	5.0	4.4	0.8	0.9	0.9
Pennisetum pedicellatum + clusterbean	4.1	5.0	4.6	0.9	1.0	1.0
SEm±	0.15	0.12		0.03	0.04	
CD at 5%	0.4	0.4		0.1	0.1	
Nitrogen levels (kg/ha)						
30	3.9	4.7	4.3	0.8	0.9	0.9
60	4.2	5.6	4.9	0.9	1.1	1.0
90	4.4	6.0	5.2	1.0	1.2	1.1
SEm±	0.15	0.12		0.03	0.04	
CD at 5%	0.4	0.4		0.1	0.1	
General mean	4.2	5.4		0.9	1.0	

FIG 14: GREEN FORAGE PRODUCTIVITY (q/ha/day)

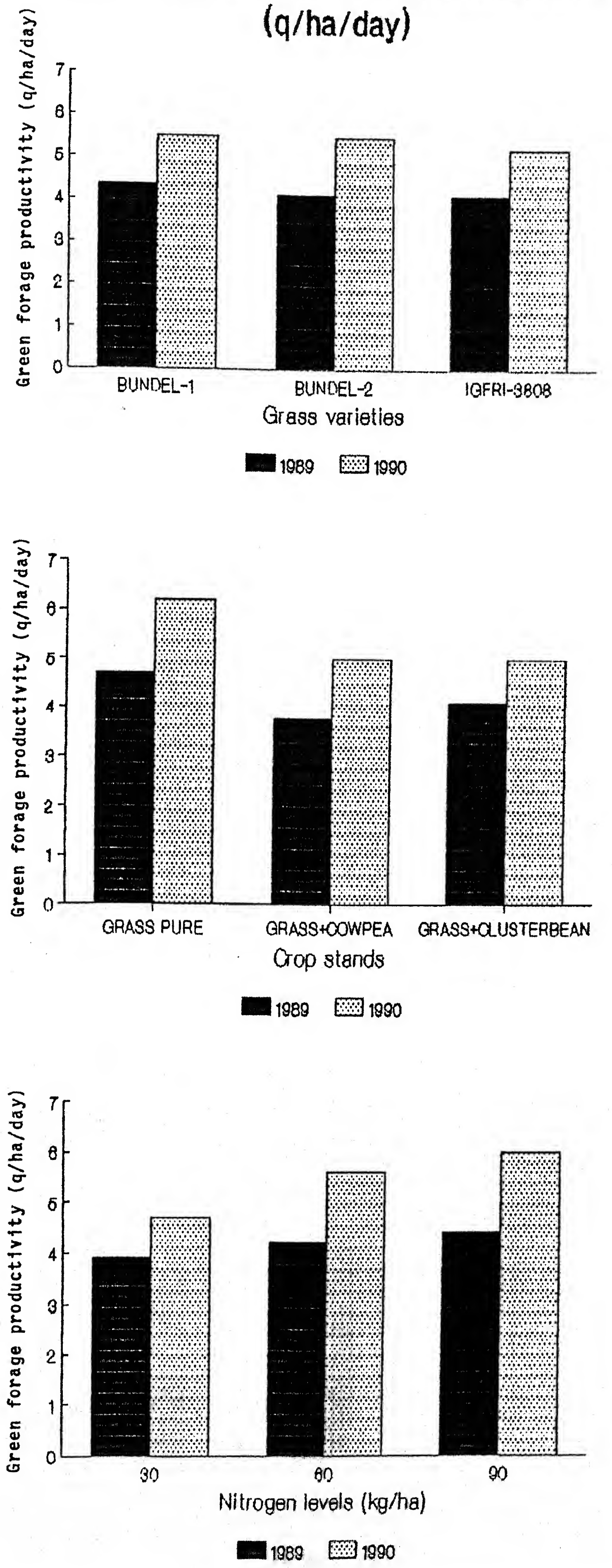
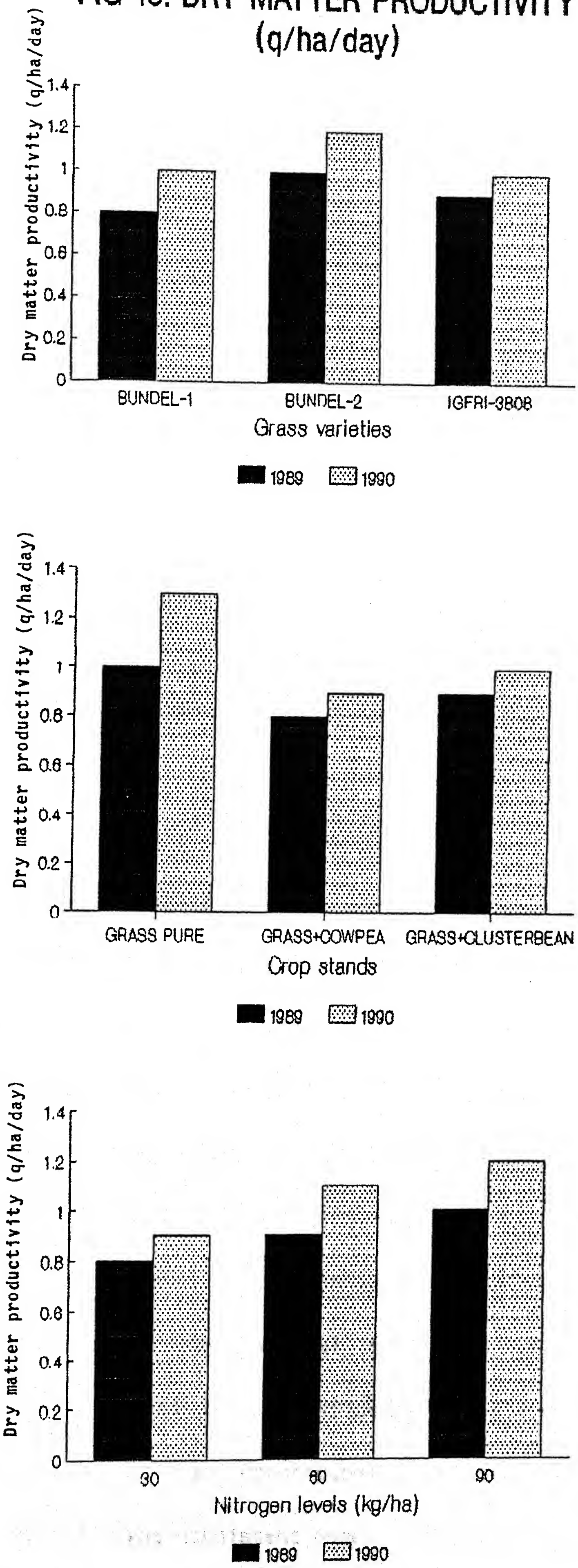


FIG 15: DRY MATTER PRODUCTIVITY (q/ha/day)



were at par in both the years. In terms of dry matter productivity, pure *Pennisetum pedicellatum* was significantly superior to its intercropping with cowpea but was at par with its intercropping with clusterbean in 1989. In 1990, *Pennisetum pedicellatum* pure recorded significantly higher productivity than its intercropping either with cowpea or clusterbean and both the intercropping systems were at par between themselves. On an average, the sward productivity could be rated as pure grass > grass +clusterbean > grass + cowpea.

Nitrogen nutrition significantly influenced the green and dry matter productivity per day in both the years. The green and dry matter productivity increased linearly with increasing levels of nitrogen from 30 to 90 kg N/ha. The application of 90 kg N/ha resulted in significantly higher productivity than 30 kg N/ha in both the years. However, the differences between 60 and 30 as well as between 90 and 60 kg N/ha were not discernible. Moreover, the average green and dry matter productivity increased progressively with increasing levels of nitrogen up to 90 kg/ha.

The interaction, crop stands x *Pennisetum pedicellatum* varieties showed significant variation in dry matter productivity in 1989 (Table 19). The maximum per day dry matter productivity of Bundel-2 pure (1.2 q/ha/day) was at par with Bundel-2 intercropped with clusterbean but significantly superior to remaining interactions. It was conspicuously noticed that productivity of Bundel-1 was consistent under different sward conditions whereas, the productivity of Bundel-2 and IGFRI-3808

Table 19. Effect of crop stands X *Pennisetum pedicellatum* varieties on dry matter productivity (q/ha/day) in 1989

Crop stands	Varieties		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
Pennisetum pedicellatum pure	0.8	1.2	1.0
Pennisetum pedicellatum + cowpea	0.8	0.8	0.8
Pennisetum pedicellatum + clusterbean	0.8	1.0	1.0
SEm+	0.03		
CD at 5%	0.2		

was comparatively lower when intercropped with cowpea.

Crude protein content (%): The data on crude protein content (%) are given in table 20 and shown in Fig. 16. In general, the crude protein content both in grass and legume remained higher in 1990 than in 1989. *Pennisetum pedicellatum* varieties differed significantly in crude protein content with the result that variety Bundel-1 registered significantly highest crude protein per cent as compared to Bundel-2 and IGFRI-3808 which in turn were at par between themselves in both the years. Legume intercropped with Bundel-1 contained maximum crude protein followed by in association with IGFRI-3808 in both the years.

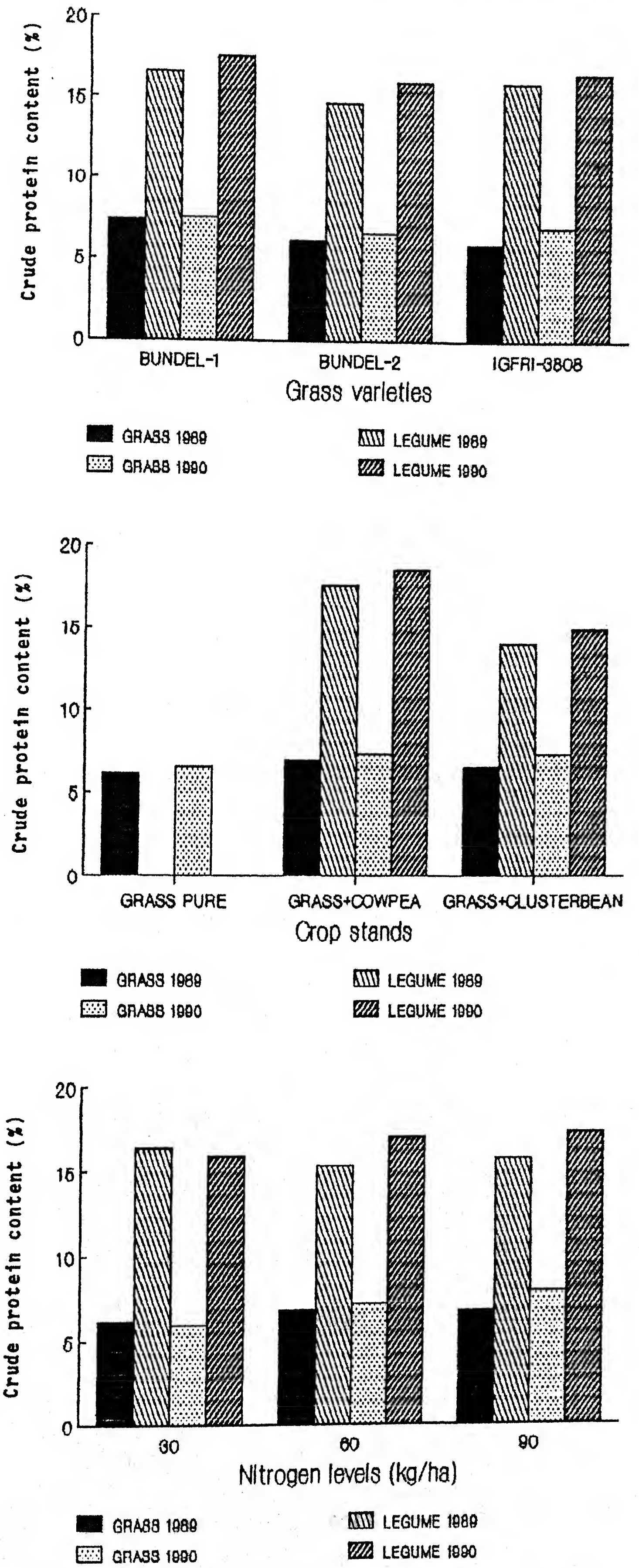
The different crop stands did not alter the crude protein content of grass significantly in 1989. However, *Pennisetum pedicellatum* intercropped with cowpea exhibited maximum crude protein content. In 1990, *Pennisetum pedicellatum* intercropped with cowpea or clusterbean resulted in significantly higher crude protein content than grass in pure stand. Grass in both the intercropping systems had numerically same crude protein content. The data averaged over the years reflected greater crude protein content in grass when intercropped with cowpea. Between legumes, cowpea contained more crude protein than clusterbean in both the years with average value of 18.1 and 14.6 per cent, respectively.

Increasing levels of nitrogen significantly influenced the crude protein content of grass component in 1990 but not in 1989. However, the increase in crude protein content of grass was observed up to 60 kg N/ha in 1989 and up to 90 kg N/ha in 1990.

Table 20. Crude protein content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	7.4	16.6	7.6	17.6	7.5	17.1
IGFRI-S-4-2-1 (Bundel-2)	6.2	14.8	6.6	16.1	6.4	15.5
IGFRI-3808	6.0	16.1	7.0	16.7	6.5	16.4
SEm±	0.29		0.18			
CD at 5%	0.8		0.5			
Crop stands						
Pennisetum pedicellatum pure	6.1		6.5		6.3	
Pennisetum pedicellatum + cowpea	7.0	17.6	7.3	18.6	7.2	18.1
Pennisetum pedicellatum + clusterbean	6.5	14.1	7.3	15.0	6.9	14.6
SEm±	0.29		0.18			
CD at 5%	NS		0.5			
Nitrogen levels (kg/ha)						
30	6.1	16.4	6.0	15.9	6.6	16.2
60	6.8	15.4	7.2	17.1	7.0	16.3
90	6.7	15.8	7.9	17.4	7.8	16.6
SEm±	0.29		0.18			
CD at 5%	NS		0.5			
General mean	6.5	15.9	7.1	16.8		

FIG 16: CRUDE PROTEIN CONTENT



Nitrogen nutrition showed favourable effect on crude protein content of legumes in 1990 only. Averaged values over the years indicated linear increase in crude protein content due to increasing levels of nitrogen both in grass and legumes.

Interaction between grass varieties x nitrogen levels (Table 21) showed significant effect on crude protein content of grass in 1990. Variety IGFRI-3808 receiving 90 kg N/ha gave maximum crude protein content of 8.3 % followed by Bundel-1 at 60 kg N/ha (8.2 %) which were at par between themselves.

Crude protein yield: The data on total crude protein yield under different treatments are presented in Table 22 and depicted in Fig. 17. The outturn of crude protein was 789.6 kg/ha in 1990 and 611.4 kg/ha in 1989. *Pennisetum pedicellatum* varieties differed significantly in crude protein yield in 1989 and variety Bundel-1 resulted in significantly higher protein yield as compared to IGFRI-3808 which in turn did not differ statistically from Bundel-2. In 1990, though the differences in crude protein yield were not significant but Bundel-1 produced maximum crude protein yield followed by Bundel-2. On the basis of average data over the years, Bundel-1 had an edge over other varieties in crude protein production.

Varying crop stands showed significant variation in crude protein yields with the result that *Pennisetum pedicellatum* intercropped with cowpea or clusterbean gave significantly higher crude protein yield per unit area over its pure stand but were

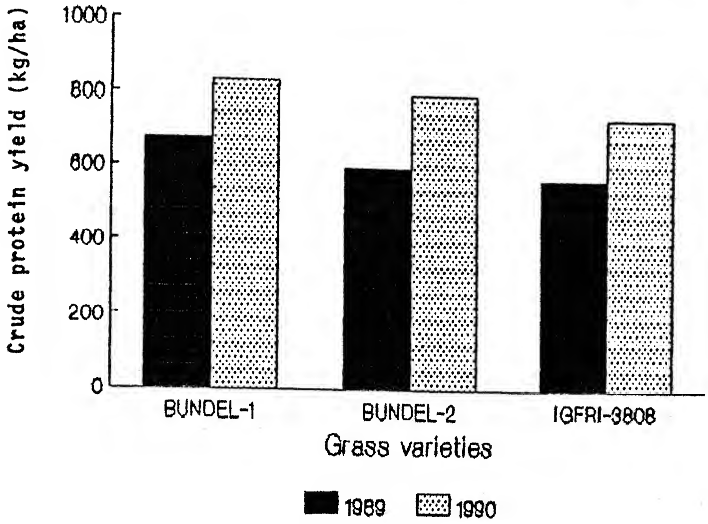
Table 21. Effect of nitrogen levels X *Pennisetum pedicellatum* varieties on crude protein content (%) of grass component in 1990

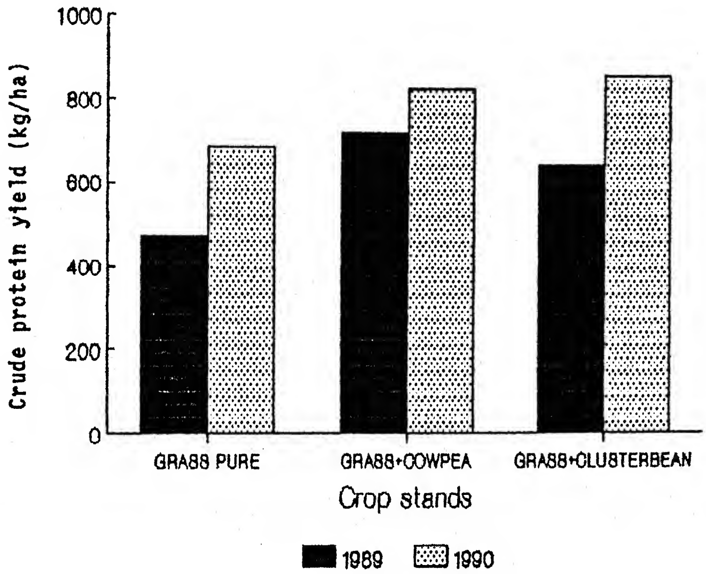
Nitrogen levels (Kg/ha)	Varieties		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
30	6.5	5.7	6.0
60	8.2	6.9	6.5
90	8.0	7.3	8.3
SEm+	0.30		
CD at 5%	0.9		

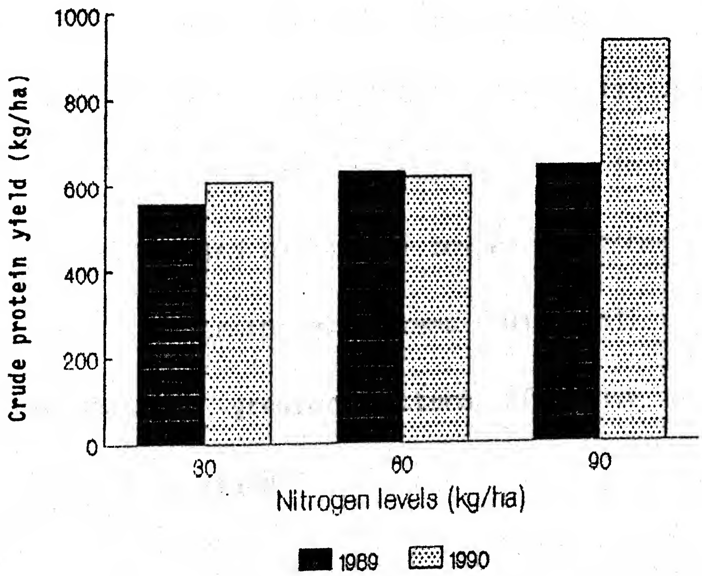
Table 22. Crude protein yield (kg/ha) in grass + legume mixed herbage

Treatments	1989	1990	Mean
Pennisetum pedicellatum varieties			
IGFRI-S-43-1 (Bundel-1)	673.0	832.0	752.5
IGFRI-S-4-2-1 (Bundel-2)	593.8	799.0	696.4
IGFRI-3808	567.4	737.9	652.7
SEm±	32.0	31.04	
CD at 5%	93.9	NS	
Crop stands			
Pennisetum pedicellatum pure	471.2	684.1	577.7
Pennisetum pedicellatum + cowpea	721.0	826.1	774.0
Pennisetum pedicellatum + clusterbean	641.0	858.7	749.9
SEm±	32.0	31.04	
CD at 5%	93.9	91.1	
Nitrogen levels (kg/ha)			
30	557.7	612.2	585.0
60	631.6	621.6	726.6
90	644.8	935.1	790.0
SEm±	32.0	31.04	
CD at 5%	NS	91.1	
General mean	611.4	789.6	

FIG 17: CRUDE PROTEIN YIELD (kg/ha) IN GRASS + LEGUME MIXED HERBAGE







at par between themselves in both the years. In 1989, grass + cowpea produced highest crude protein yield whereas, in 1990, grass + clusterbean produced highest crude protein yield. The data averaged over the years indicated that the crude protein production was in the order of grass+cowpea > grass + clusterbean > grass pure.

Nitrogen fertilization influenced the crude protein production significantly in 1990 but not in 1989. In 1989, however, crude protein increased with an increase in nitrogen level up to 90 kg N/ha. In 1990, each successive dose of nitrogen caused significant increase in crude protein yield. The average data for two years indicated that an increase in nitrogen from 30 to 60 kg/ha increased the crude protein yield by 141.6 kg/ha whereas increase in nitrogen from 60 to 90 kg/ha gave an additional crude protein yield of only 63.4 kg/ha.

In 1989, the interaction between grass varieties x crop stands was significant with the result that variety Bundel-1 intercropped with cowpea produced significantly highest crude protein (887.6 kg/ha) as compared to remaining combinations (Table 23). The other treatment combinations in order were Bundel-1 + clusterbean and Bundel-2 + cowpea. Further, it could be noted that intercropping systems with all the grass varieties resulted in greater outturn of crude protein as compared to their sole stand.

Table 23. Effect of crop stands X *Pennisetum pedicellatum* varieties on crude protein yield (kg/ha) in 1989

Crop stands	Varieties		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
Pennisetum pedicellatum pure	434.4	502.1	477.1
Pennisetum pedicellatum + cowpea	887.6	681.3	596.9
Pennisetum pedicellatum + clusterbean	696.9	598.0	628.2
SEm+	55.44		
CD at 5%	162.6		

Water soluble carbohydrates (WSC): The data in Table 24 and Fig. 18 indicated that WSC content of *Pennisetum pedicellatum* in 1989 was higher (4.8 %) as compared to that in 1990 (3.5 %). Similarly WSC content of legume component in 1989 was more than twice of that in 1990.

The treatment variables exercised significant effect on WSC content of grass in both the years except nitrogen levels in 1989. In 1989, varieties IGFRI-3808 and Bundel-2 showed statistically similar WSC content but significantly greater than Bundel-1. In 1990, Bundel -1 and IGFRI-3808 were at par between themselves but significantly superior to Bundel-2 in this regard. Legume in association with IGFRI -3808 produced maximum WSC content in both the years. On an average, the WSC content of legume in association with IGFRI-3808 was 3.6 % against 3.1 % in association with both Bundel-1 and Bundel-2.

Pennisetum pedicellatum intercropped with cowpea had significantly higher WSC content than pure grass or its intercropping with clusterbean in both the years. The data averaged over the years also gave similar pattern with respect to crop stands.

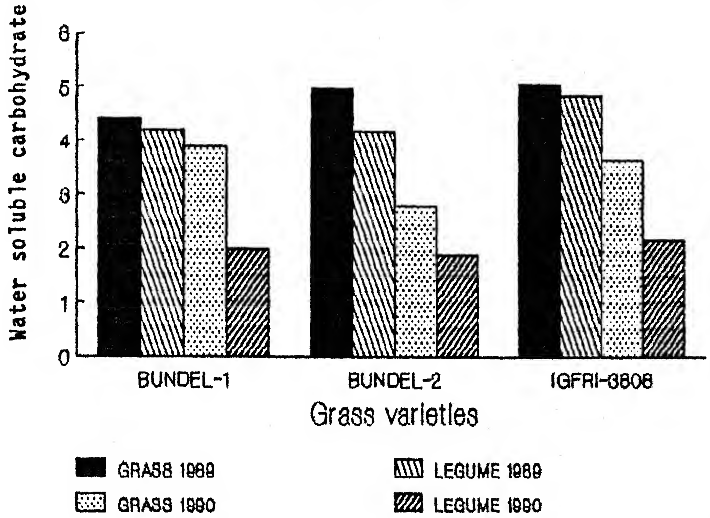
Cowpea intercropped with *Pennisetum pedicellatum* indicated higher WSC content than intercropped clusterbean in 1989, whereas in 1990, the trend was reversed and was also maintained for average data.

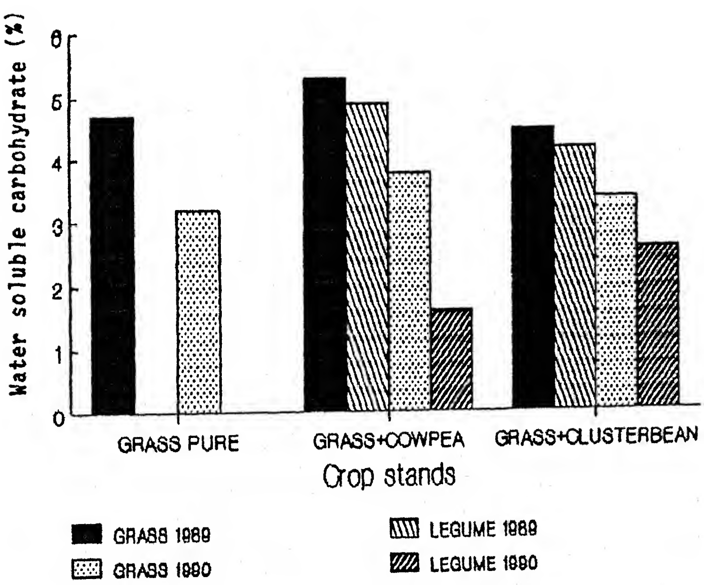
In 1989, the increasing levels of nitrogen increased the content of WSC in grass but the differences were statistically

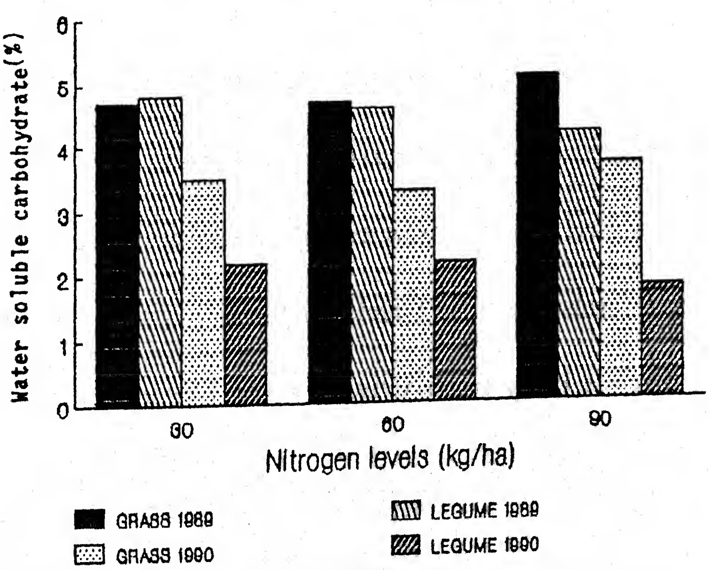
Table 24. Water soluble carbohydrates content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	4.4	4.2	3.9	2.0	4.2	3.1
IGFRI-S-4-2-1 (Bundel-2)	5.0	4.2	2.8	1.9	3.9	3.1
IGFRI-3808	5.1	4.9	3.7	2.2	4.4	3.6
SEm±	0.13		0.10			
CD at 5%	0.38		0.29			
Crop stands						
Pennisetum pedicellatum pure	4.7		3.2		4.0	
Pennisetum pedicellatum + cowpea	5.3	4.9	3.8	1.6	4.6	3.3
Pennisetum pedicellatum + clusterbean	4.5	4.2	3.4	2.6	4.0	3.4
SEm±	0.13		0.10			
CD at 5%	0.38		0.29			
Nitrogen levels (kg/ha)						
30	4.7	4.8	3.5	2.2	4.1	3.5
60	4.7	4.6	3.3	2.2	4.0	3.4
90	5.1	4.2	3.7	1.8	4.4	3.0
SEm±	0.13		0.10			
CD at 5%	NS		0.29			
General mean	4.8	4.5	3.5	2.1		

FIG 18: WATER SOLUBLE CARBOHYDRATE CONTENT







not significant. In 1990, application of 90 kg N/ha produced significantly higher WSC content than 60 kg N/ha. The differences between 30 and 60 kg N/ha as well as between 30 and 90 kg N/ha were not significant. On an average, however, the highest WSC content was recorded with 90 kg N/ha. In legumes, water soluble carbohydrates content declined with an increase in N levels in both the years.

The interaction between varieties and nitrogen levels for WSC was significant in both the years (Table 25.). In 1989, WSC content of IGFRI-3808 was maximum (5.4 %) at 60 kg N/ha but did not differ significantly from its content at 30 and 90 kg N/ha and that of Bundel-1 at 90 kg N/ha and Bundel-2 at all the N levels. However, IGFRI-3808 had significantly higher WSC content than Bundel-1 at 30 and 60 kg N/ha. In 1990, IGFRI-3808 at 30 kg N/ha gave maximum WSC content followed by Bundel-1 at the same level of nitrogen nutrition.

Interaction of crop stands x levels of nitrogen (Table 25) recorded significant variation in WSC content in *Pennisetum pedicellatum* in 1990 with the result that grass intercropped with cowpea receiving 30 kg N/ha showed maximum WSC content (4.1 %) which was significantly greater than the remaining interactions except *Pennisetum pedicellatum* intercropped with cowpea receiving 90 kg N/ha.

Oxalate content: The data on oxalate content expressed in per cent at harvest in *Pennisetum pedicellatum* are tabulated in Table

Table 25. Effect of nitrogen levels X *Pennisetum pedicellatum* varieties and nitrogen levels X crop stands on water soluble carbohydrates content (%) of grass component

Nitrogen levels (kg/ha)	1989 Varieties			1990 Varieties			1990 Crop stands		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808	*Pennisetum pedicellatum* pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean
30	4.2	5.3	4.8	4.0	2.2	4.1	3.3	4.1	3.0
60	4.0	4.8	5.4	3.7	3.8	3.4	2.9	3.4	3.6
90	5.2	5.0	5.1	4.0	3.3	3.8	3.5	3.9	3.7
SEm±	0.22			0.09			0.09		
CD at 5%	0.6			0.3			0.3		

26 and shown in Fig. 19. The grass exhibited lower oxalate content in 1989 (2.8 %) than in 1990 (3.2 %). The varieties, crop stands and nitrogen levels caused significant variation in oxalate content in 1989 but not in 1990. In 1989, the oxalate content of Bundel-2 was at par with IGFRI-3808 but significantly lower than Bundel-1. In 1990 also, Bundel-2 contained lower oxalate content than other varieties. The average oxalate content worked out to be minimum (2.8 %) in Bundel-2 and maximum in Bundel-1 (3.3 %).

In 1989, *Pennisetum pedicellatum* intercropped with cowpea showed significantly less oxalate content (2.6 %) than pure grass or its intercropping with clusterbean (2.9 %). In 1990, however, pure stand of grass contained lowest oxalate content. On an average, the differences in oxalate content for crop stands were not tangible.

In 1989, application of 90 kg N/ha exhibited significantly lowest oxalate content in *Pennisetum pedicellatum* than 60 kg N/ha but both these levels in turn were at par with 30 kg N/ha. In 1990, oxalate content decreased with increasing levels of nitrogen up to 60 kg N/ha and remained constant thereafter. However, average oxalate content over the years gradually decreased with increasing levels of nitrogen from 30 to 90 kg/ha.

Pennisetum pedicellatum varieties interacted significantly with nitrogen levels in modifying the oxalate content (Table 27)

Table 26. Total oxalate content (%) in *Pennisetum pedicellatum*

Treatments	1989	1990	Mean
Pennisetum pedicellatum varieties			
IGFRI-S-43-1 (Bundel-1)	3.0	3.5	3.3
IGFRI-S-4-2-1 (Bundel-2)	2.6	2.9	2.8
IGFRI-3808	2.7	3.3	3.0
SEm±	0.08	0.20	
CD at 5%	0.2	NS	
Crop stands			
Pennisetum pedicellatum pure	2.9	3.0	3.0
Pennisetum pedicellatum + cowpea	2.6	3.3	3.0
Pennisetum pedicellatum + clusterbean	2.9	3.3	3.1
SEm±	0.08	0.20	
CD at 5%	0.23	NS	
Nitrogen levels (kg/ha)			
30	2.8	3.5	3.2
60	2.9	3.1	3.0
90	2.6	3.1	2.9
SEm±	0.08	0.20	
CD at 5%	0.23	NS	
General mean	2.8	3.2	

FIG 19: TOTAL OXALATE CONTENT IN *Pennisetum pedicellatum*

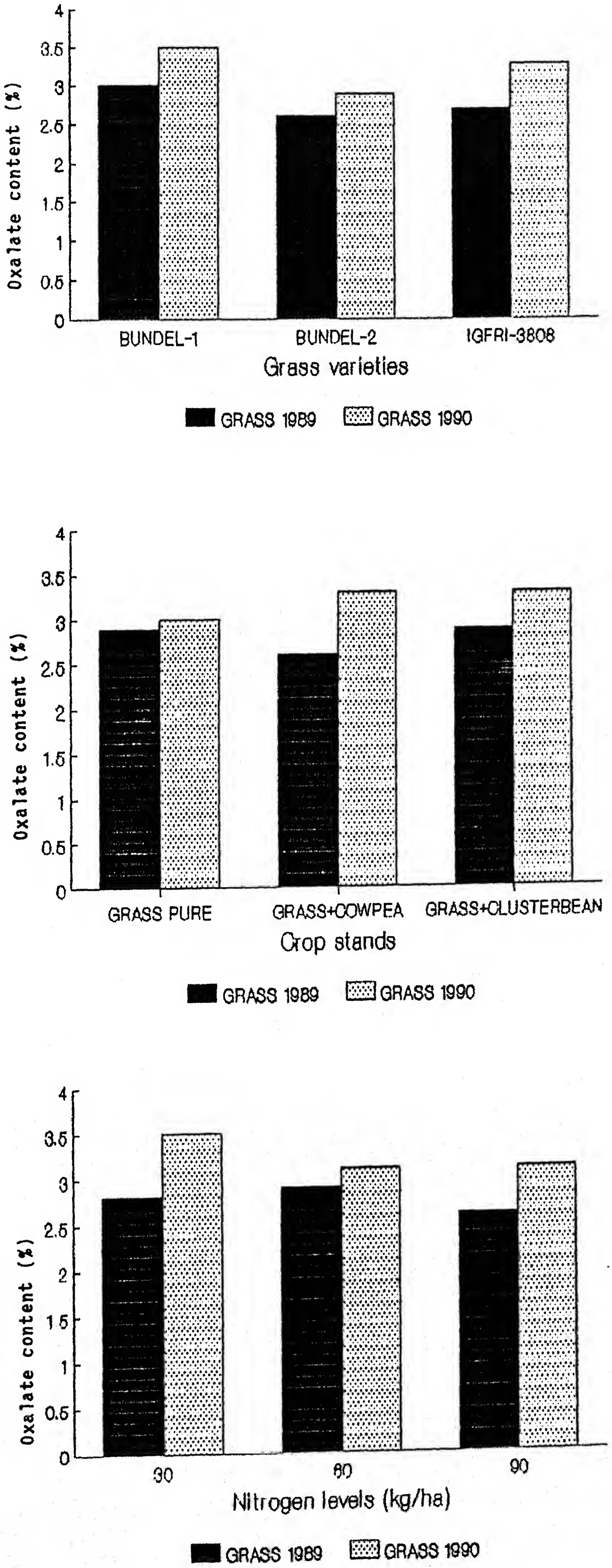


Table 27. Effect of nitrogen levels X *Pennisetum pedicellatum* varieties on oxalate content (%) in 1989

Nitrogen levels (kg/ha)	Varieties		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
30	3.0	2.7	3.0
60	3.2	2.9	2.7
90	2.9	3.0	2.4
SEm+	0.14		
CD at 5%	0.2		

with the result that variety IGFRI-3808 fertilized with 90 kg N/ha showed lowest oxalate content as compared to remaining varieties x nitrogen levels interactions.

Fibre Fractions:

Neutral detergent fibre (NDF): The data on neutral detergent fibre content (Table 28 and Fig. 20) indicated that the mean NDF content of *Pennisetum pedicellatum* was practically similar for both the years. However, in legumes it was higher in 1990 (52.3 %) than in 1989 (49.3 %). None of the treatment variables influenced the neutral detergent fibre content significantly in both the years. However, minimum neutral detergent fibre was observed in Bundel-1 and maximum in Bundel-2.

The neutral detergent fibre content of legumes did not undergo appreciable change due to its association with different grass varieties as the values ranged from 48.6 to 49.4 % in 1989 and from 52.9 to 53.5 % in 1990. Legume associated with Bundel-2 exhibited minimum content of neutral detergent fibre.

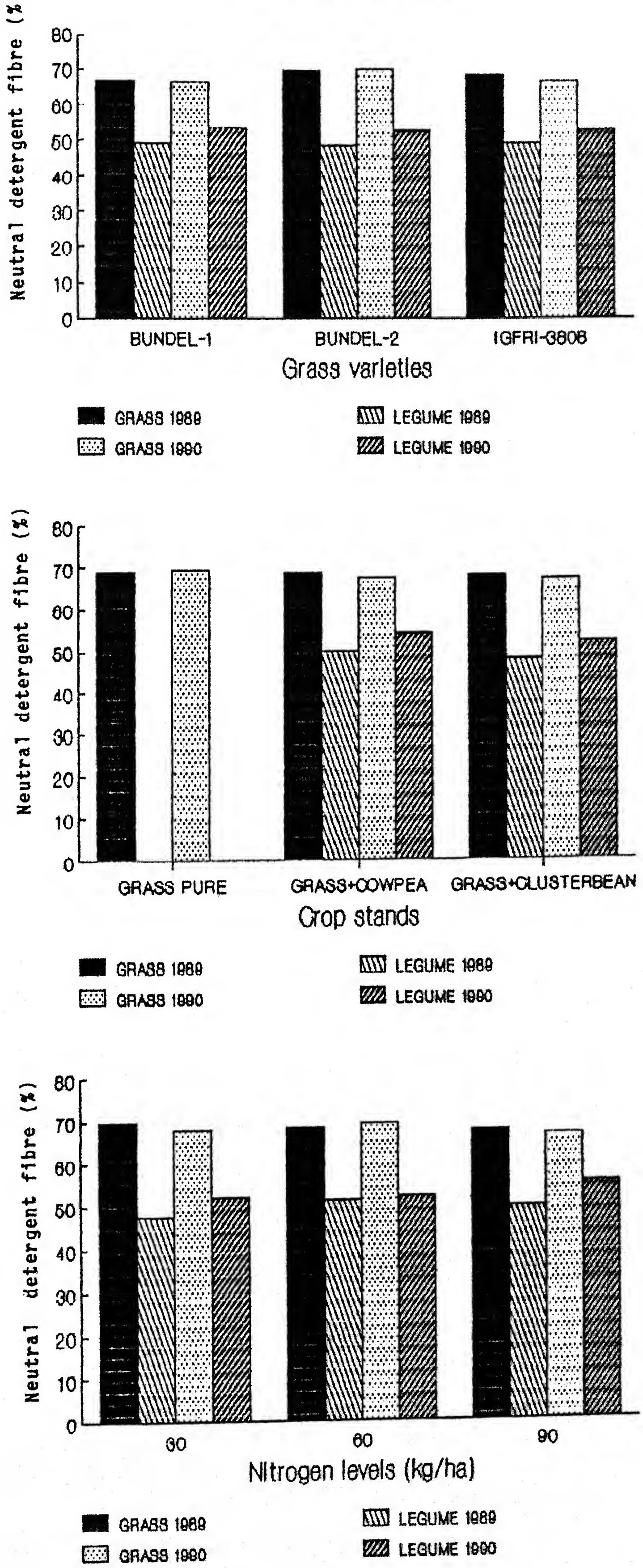
Pennisetum pedicellatum intercropped with clusterbean indicated lowest values of neutral detergent fibre both in grass and legume in both the years. The neutral detergent fibre content remained consistently high when grass was grown without legume.

The increasing doses of nitrogen gradually decreased the NDF content of *Pennisetum pedicellatum* in 1989. In 1990, also the minimum NDF occurred with 90 kg N/ha. In case of legume, the NDF

Table 28. Neutral detergent fibre (NDF) content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	67.0	49.3	66.6	53.5	66.8	51.4
IGFRI-S-4-2-1 (Bundel-2)	69.6	48.6	70.4	52.9	70.0	50.8
IGFRI-3808	69.0	49.4	67.3	53.2	68.2	51.3
SEm±	1.09		1.16			
CD at 5%	NS		NS			
Crop stands						
Pennisetum pedicellatum pure	68.9		69.4		69.2	
Pennisetum pedicellatum + cowpea	68.6	50.2	67.6	54.3	68.1	52.3
Pennisetum pedicellatum + clusterbean	68.2	48.0	67.3	52.1	67.8	50.1
SEm±	1.09		1.16			
CD at 5%	NS		NS			
Nitrogen levels (kg/ha)						
30	69.5	47.6	67.9	52.1	68.7	49.9
60	68.4	51.3	69.4	52.2	68.9	51.8
90	67.8	49.7	66.9	55.3	67.4	52.5
SEm±	1.09		1.16			
CD at 5%	NS		NS			
General mean	68.6	49.3	68.1	53.2		

FIG 20: NEUTRAL DETERGENT FIBRE (NDF) CONTENT



content increased up to 60 kg N/ha in 1989 and up to 90 kg N/ha in 1990.

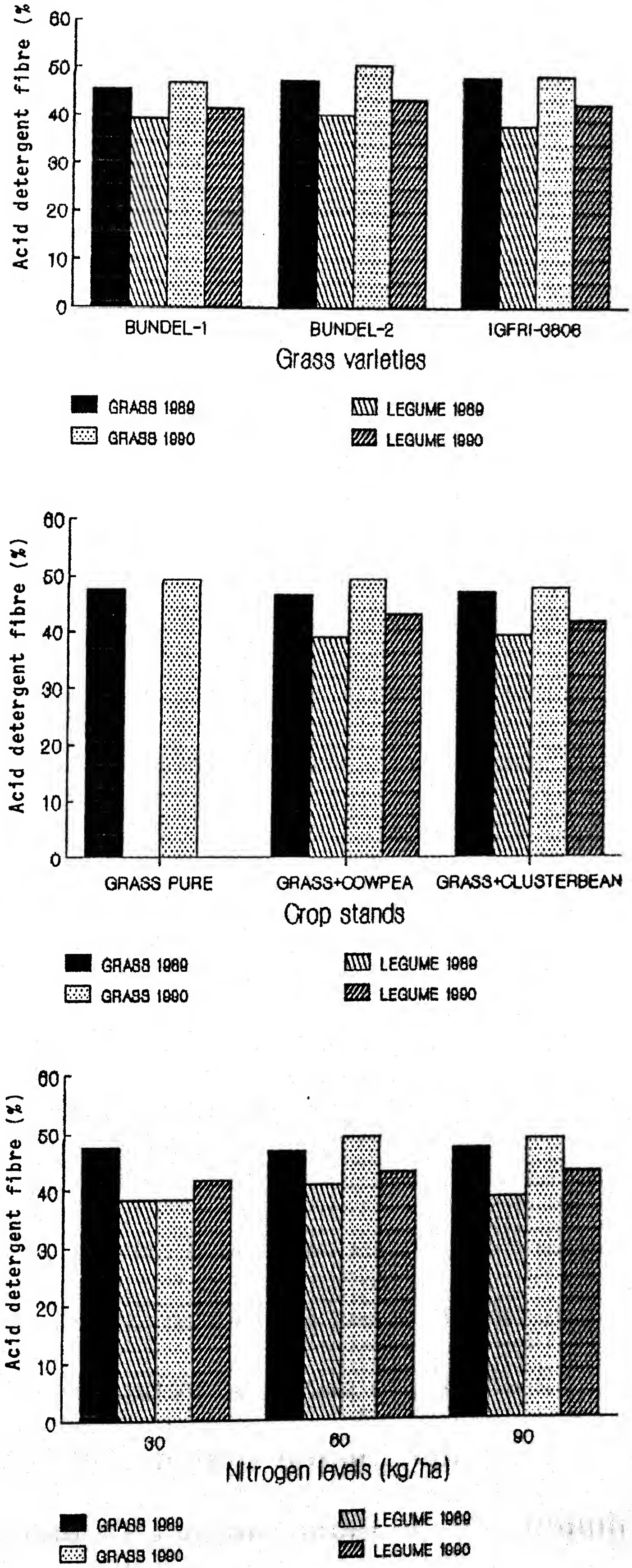
Acid detergent fibre (ADF): The data on acid detergent fibre content (Table 29 and Fig. 21.) revealed that average acid detergent fibre content of *Pennisetum pedicellatum* was 47.2 % in 1989 and 48.8 % in 1990. The corresponding values for legumes were 39.3 and 42.7 per cent. In 1989, grass varieties did not show significant differences in acid detergent fibre. However, minimum ADF content was observed in Bundel-1 and maximum in IGFRI-3808. In 1990, varieties Bundel-1 and IGFRI-3808 contained statistically similar ADF content but significantly lower than Bundel-2. On an average, the varieties contained ADF in order of Bundel-1 < IGFRI-3808 < Bundel-2. Legume exhibited minimum ADF content in association with grass variety IGFRI-3808 in 1989 and with Bundel-1 in 1990 whereas the maximum content was found in association with Bundel-2 in both the years. Averaged over the years, the minimum ADF content in legume was observed when grown with variety IGFRI-3808.

Acid detergent fibre did not show significant variation due to differential crop stands in both the years. However, lowest ADF content in *Pennisetum pedicellatum* occurred when it was intercropped with cowpea in 1989 and with clusterbean in 1990. There was no perceptible difference in ADF content of two forage legumes in 1989 whereas, in 1990 clusterbean contained lower ADF than cowpea. Similar trend was maintained with respect to average values over the years.

Table 29. Acid detergent fibre (ADF) content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	45.7	39.4	46.9	41.6	46.3	40.5
IGFRI-S-4-2-1 (Bundel-2)	47.5	40.3	50.9	43.7	49.2	42.0
IGFRI-3808	48.2	38.1	48.6	42.7	48.4	40.4
SEm±	0.82		0.62			
CD at 5%	NS		2.03			
Crop stands						
Pennisetum pedicellatum pure	47.6		49.2		48.4	
Pennisetum pedicellatum + cowpea	46.7	39.2	49.4	43.3	48.1	41.3
Pennisetum pedicellatum + clusterbean	47.2	39.4	47.8	42.0	47.5	40.7
SEm±	0.82		0.62			
CD at 5%	NS		NS			
Nitrogen levels (kg/ha)						
30	47.5	38.3	48.4	41.9	48.0	40.1
60	46.7	40.8	49.2	43.1	48.0	42.0
90	47.2	38.7	48.8	43.0	48.0	40.9
SEm±	0.82		0.62			
CD at 5%	NS		NS			
General mean	47.2	39.3	48.8	42.7		

FIG 21: ACID DETERGENT FIBRE (ADF) CONTENT



Varying nitrogen levels did not bring out significant variation in acid detergent fibre content in both the years. Minimum ADF content was however, observed with 60 kg N/ha in 1989 and with 30 kg N/ha in 1990. Averaged over two years, the different nitrogen levels gave numerically same ADF values. In case of legumes, application of 30 kg N/ha gave minimum ADF content in both the years.

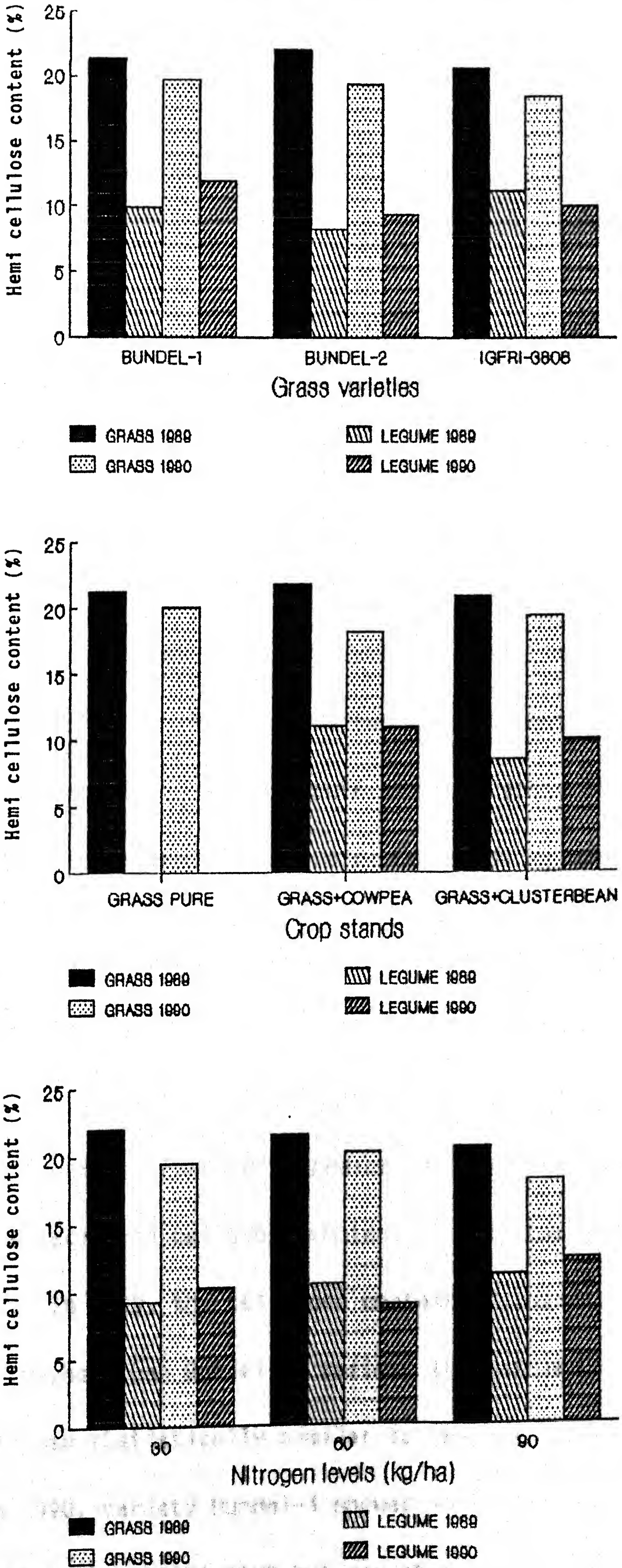
Hemicellulose: The mean hemicellulose content in *Pennisetum pedicellatum* was higher in 1989 than in 1990 (Table 30 and Fig. 22) but its content in legumes remained practically the same over the years. The hemicellulose content of *Pennisetum pedicellatum* varieties showed no significant variation, however, variety IGFRI-3808 exhibited lowest hemicellulose content in both the years. On the other hand, Bundel-2 recorded its highest content in 1989 and Bundel-1 in 1990. On an average, Bundel-1 and Bundel-2 had almost similar hemicellulose content but more than IGFRI-3808. The legume intercropped with Bundel-2 exhibited consistently lowest hemicellulose in individual year and also over the years.

The crop stands showed no significant variation in hemicellulose content in both the years. There was not much difference in hemicellulose content of grass under different crop stands in 1989. In 1990, however, grass intercropped with cowpea gave comparatively lower content of hemicellulose. The average hemicellulose content over the years was minimum (20.1 %) for *Pennisetum pedicellatum* when intercropped with cowpea while

Table 30. Hemicellulose content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	21.3	9.9	19.7	11.9	20.5	10.9
IGFRI-S-4-2-1 (Bundel-2)	22.1	8.3	19.5	9.5	20.8	8.9
IGFRI-3808	20.8	11.3	18.7	10.2	19.8	10.8
SEm±	0.48		0.93			
CD at 5%	NS		NS			
Crop stands						
Pennisetum pedicellatum pure	21.3		20.1		20.7	
Pennisetum pedicellatum + cowpea	21.9	11.1	18.2	11.0	20.1	11.1
Pennisetum pedicellatum + clusterbean	21.0	8.6	19.5	10.1	20.3	9.4
SEm±	0.48		0.93			
CD at 5%	NS		NS			
Nitrogen levels (kg/ha)						
30	22.0	9.3	19.5	10.3	20.8	9.8
60	21.5	10.5	20.2	9.0	20.9	9.8
90	20.6	11.1	18.1	12.3	19.4	11.7
SEm±	0.48		0.93			
CD at 5%	NS		NS			
General mean	21.4	10.0	19.1	10.6		

FIG 22: HEMICELLULOSE CONTENT



pure grass reflected its maximum value (20.7 %). Between legumes, the hemicellulose content was consistently less in clusterbean than cowpea.

The hemicellulose content remained unaltered by varying doses of nitrogen in both the years. Application of 90 kg N/ha resulted in minimum hemicellulose content in *Pennisetum pedicellatum* pure but accumulated its maximum content in legumes in both the years. The average data on hemicellulose content over the years too evinced similar pattern.

The significant crops stand x nitrogen levels interaction in 1990 (Table 31) showed that *Pennisetum pedicellatum* intercropped with cowpea at 30 kg N/ha contained significantly higher hemicellulose content (23.1 %) than pure stand of grass at 60 kg N/ha as well as intercropped with clusterbean at 30 kg N/ha.

Cellulose: The mean cellulose content both in *Pennisetum pedicellatum* and legume was higher in 1990 than in 1989 (Table 32 and Fig. 23). In general, the cellulose content in legume was 2/3rd of that in grass. *Pennisetum pedicellatum* varieties showed significant variation in cellulose content in both the years of investigation. In 1989, the cellulose content of Bundel-2 was significantly higher than Bundel-1. Variety IGFRI-3808 however, contained cellulose statistically similar to that of Bundel-1 and Bundel-2. In 1990, variety Bundel-1 showed significantly lower cellulose content than IGFRI-3808 but was at par with Bundel-2 which in turn did not differ from each other. The data averaged

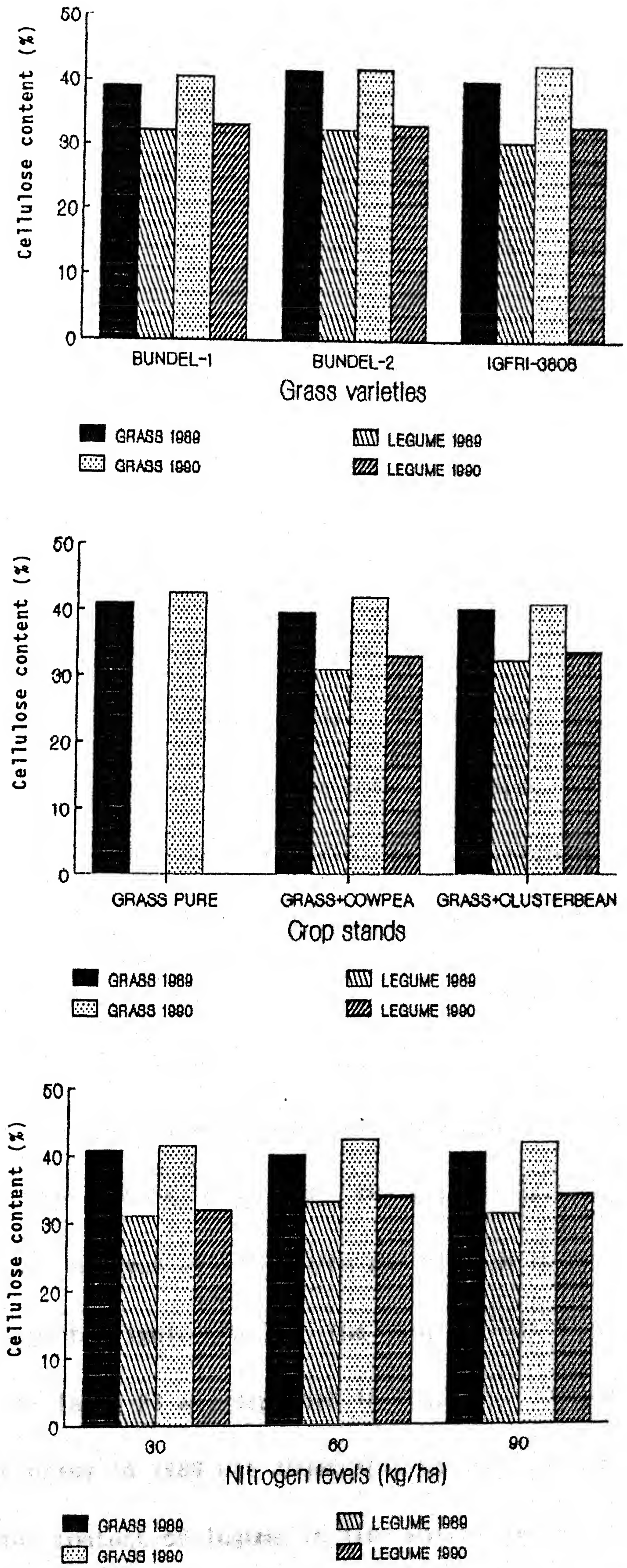
Table 31. Effect of crop stands X nitrogen levels on hemicellulose content (%) of grass component

Crop stands	1990		
	Nitrogen levels (kg/ha)		
	30	60	90
Pennisetum pedicellatum pure	20.6	13.8	22.4
Pennisetum pedicellatum + cowpea	23.1	19.5	18.2
Pennisetum pedicellatum + clusterbean	16.8	19.6	18.1
SEm±	1.60		
CD at 5%	5.2		

Table 32. Cellulose content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	39.0	32.2	40.5	33.2	39.8	32.7
IGFRI-S-4-2-1 (Bundel-2)	41.6	32.5	42.1	33.4	41.9	33.0
IGFRI-3808	40.4	30.8	43.1	33.5	41.8	32.2
SEm±	0.58		0.48			
CD at 5%	1.9		1.6			
Crop stands						
Pennisetum pedicellatum pure	41.1		42.6		41.9	
Pennisetum pedicellatum + cowpea	39.6	31.1	42.1	33.0	40.9	32.1
Pennisetum pedicellatum + clusterbean	40.2	32.5	41.1	33.7	40.7	33.1
SEm±	0.58		0.48			
CD at 5%	NS		NS			
Nitrogen levels (kg/ha)						
30	40.8	31.1	41.5	32.0	41.2	31.6
60	40.0	33.1	42.3	33.9	41.2	33.5
90	40.2	31.3	41.9	34.1	41.1	32.7
SEm±	0.58		0.48			
CD at 5%	NS		NS			
General mean	40.3	31.8	41.9	33.4		

FIG 23: CELLULOSE CONTENT



over the years indicated that the variety Bundel-1 exhibited lower cellulose content than Bundel-2 and IGFRI-3808 which had similar cellulose content. In 1989, the cellulose content of legume was low in association with IGFRI-3808 as compared to its association with Bundel-1 and Bundel-2. In 1990, however, legume exhibited similar cellulose content with all the grass varieties.

Differential crop stands did not cause significant variation in cellulose content of grass in any of the years. However, grass accumulated maximum cellulose content in pure stand in both the years. Average data also indicated that association of grass either with cowpea or clusterbean exhibited lower cellulose content than pure stand of grass. Clusterbean showed higher cellulose content than cowpea in both the years.

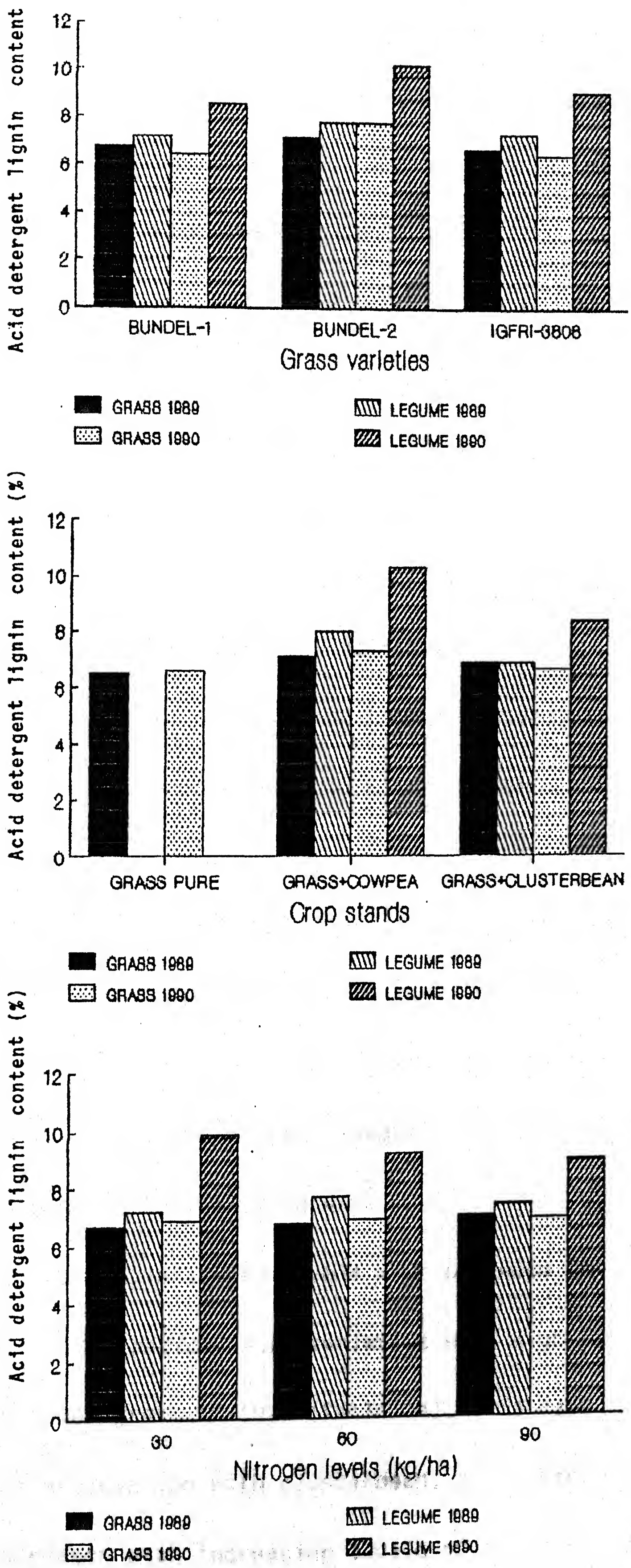
Nitrogen levels did not influence the cellulose content of *Pennisetum pedicellatum* significantly in any of the years. In 1989, maximum cellulose content in grass was recorded with 30 kg N/ha. In 1990, the highest cellulose content was obtained with 60 kg N/ha. Legume showed maximum cellulose content at 60 kg N/ha in 1989 and at 90 kg N/ha in 1990. The average cellulose content in legume was maximum at 60 kg N/ha and minimum at 30 kg N/ha.

Acid detergent lignin (ADL): The data on lignin content are presented in Table 33 and depicted in Fig. 24. The mean lignin content of grass in 1989 was comparable to that in 1990 whereas, the lignin content of legume in 1990 was higher by 1.8 % over that in 1989. The lignin content of *Pennisetum pedicellatum* varieties did not vary significantly in 1989 whereas, in 1990

Table 33. Acid detergent lignin (ADL) content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	6.7	7.2	6.4	8.5	6.6	7.9
IGFRI-S-4-2-1 (Bundel-2)	7.2	7.8	7.8	10.3	7.5	9.1
IGFRI-3808	6.7	7.4	6.5	9.2	6.6	8.3
SEm±	0.32		0.19			
CD at 5%	NS		0.62			
Crop stands						
Pennisetum pedicellatum pure	6.5		6.6		6.6	
Pennisetum pedicellatum + cowpea	7.1	8.0	7.3	10.3	7.2	9.2
Pennisetum pedicellatum + clusterbean	6.9	6.9	6.7	8.4	6.8	7.7
SEm±	0.32		0.19			
CD at 5%	NS		NS			
Nitrogen levels (kg/ha)						
30	6.7	7.2	6.9	9.9	6.8	8.6
60	6.8	7.7	6.9	9.2	6.9	8.5
90	7.0	7.4	6.9	8.9	7.0	8.2
SEm±	0.32		0.19			
CD at 5%	NS		NS			
General mean	6.8	7.5	6.9	9.3		

FIG 24: ACID DETERGENT LIGNIN (ADL) CONTENT



significantly lower lignin content was observed in Bundel-1 and IGFRI-3808 as compared to Bundel-2. On an average, the lignin content in Bundel-1 and IGFRI-3808 was numerically the same (6.6 %) and lower than Bundel-2 (7.5 %). The legume in association with Bundel-1 contained minimum lignin whereas, its content was maximum in association with Bundel-2 in both the years.

Differential crop stands brought no tangible variation in lignin content of grass. However, the minimum lignin content was observed in *Pennisetum pedicellatum* pure while it was maximum when grass was intercropped with cowpea. The lignin content in cowpea was more than clusterbean in both the years.

Nitrogen levels could not bring tangible change in lignin content of *Pennisetum pedicellatum* in both the years. In 1989, a slender increase in lignin content of grass was noticed with increasing levels of nitrogen. In 1990, however, all the levels of nitrogen exhibited numerically the same lignin content. The data averaged over the years showed that the lignin content increased in grass and decreased in legume with an increase in doses of nitrogen from 30 to 90 kg N/ha.

The interactions, nitrogen levels x crop stands and nitrogen levels x *Pennisetum pedicellatum* varieties were significant for lignin content of grass in 1990 (Table 34). In case of pure grass and its association with clusterbean, the lignin content gradually increased with increasing levels of nitrogen whereas, in case of grass intercropped with cowpea its content decreased. The grass grown with cowpea at 30 kg N/ha and with clusterbean at

Table 34. Effect of nitrogen levels X crop stands and nitrogen levels X *Pennisetum pedicellatum* varieties on lignin content of grass (%) in 1990

Nitrogen levels (kg/ha)	Crop stands			Varieties		
	Pennisetum pedicellatum pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
30	6.1	8.5	6.1	7.1	6.5	7.1
60	6.8	7.3	6.5	6.7	6.3	7.6
90	7.0	6.2	7.4	5.3	6.7	8.6
SEm±	0.33			0.33		
CD at 5%	1.1			1.1		

90 kg N/ha exhibited statistically similar lignin content but higher than other combinations. Variety IGFRI-3808 receiving 60 or 90 kg N/ha showed similar lignin content but significantly greater than remaining interactions of grass varieties x nitrogen levels. With increasing levels of nitrogen from 30 to 90 kg/ha, the lignin content decreased in Bundel-1, increased in IGFRI-3808 and remained static in Bundel-2.

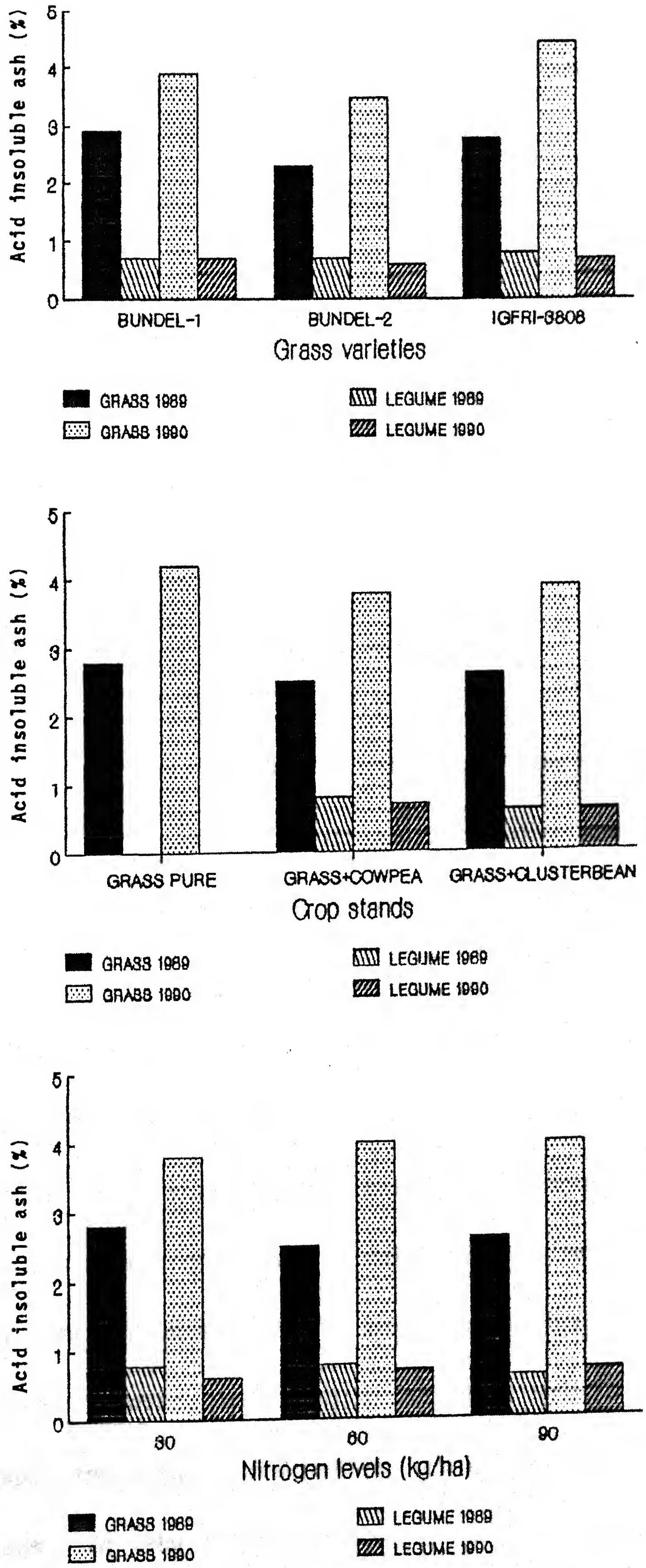
Acid insoluble ash (Plant silica): Average acid insoluble ash content of *Pennisetum pedicellatum* (Table 35 and Fig. 25) was less (2.6 %) in 1989 than in 1990 (4.0 %) while the values for legume were identical (0.7 %) in both the years. None of the treatment variables brought out significant variation in ash content in both the years. Variety Bundel-2 gave lowest ash content consistently. Bundel-1 in 1989 and IGFRI-3808 in 1990 registered maximum content of acid insoluble ash. Legume in association with Bundel-1 and Bundel-2 exhibited similar and lower ash content than in association with IGFRI-3808 in 1989 whereas in 1990, legume in association with Bundel-1 and IGFRI-3808 gave similar but higher ash content than in association with Bundel-2. On an average, the ash content of legume was marginally higher in association with IGFRI-3808.

Pennisetum pedicellatum grown in pure stand contained maximum acid insoluble ash followed by grass intercropped with clusterbean and cowpea in both the years. Between legumes, cowpea contained higher ash per cent than clusterbean throughout.

Table 35. Acid insoluble ash content (%)

Treatments	1989		1990		Mean	
	Grass	Legume	Grass	Legume	Grass	Legume
Pennisetum pedicellatum varieties						
IGFRI-S-43-1 (Bundel-1)	2.9	0.7	3.9	0.7	3.4	0.7
IGFRI-S-4-2-1 (Bundel-2)	2.3	0.7	3.5	0.6	2.9	0.7
IGFRI-3808	2.8	0.8	4.5	0.7	3.7	0.8
SEm±	0.20		0.24			
CD at 5%	NS		NS			
Crop stands						
Pennisetum pedicellatum pure	2.8		4.2		3.5	
Pennisetum pedicellatum + cowpea	2.5	0.8	3.8	0.7	3.2	0.8
Pennisetum pedicellatum + clusterbean	2.6	0.6	3.9	0.6	3.3	0.6
SEm±	0.20		0.24			
CD at 5%	NS		NS			
Nitrogen levels (kg/ha)						
30	2.8	0.8	3.8	0.6	3.3	0.7
60	2.5	0.8	4.0	0.7	3.3	0.8
90	2.6	0.6	4.0	0.7	3.3	0.7
SEm±	0.20		0.24			
CD at 5%	NS		NS			
General mean	2.6	0.7	4.0	0.7		

FIG 25: ACID INSOLUBLE ASH (PLANT SILICA) CONTENT



Nitrogen levels could not bring out significant variation in acid insoluble ash content of *Pennisetum pedicellatum* in both the years. Averaged over the years, the ash content worked out to be numerically the same at all the levels of nitrogen. Like grass, the ash content of legume was also of similar order at varying levels of nitrogen.

Nitrogen Uptake:

The perusal of the data on nitrogen uptake under different treatments (Table 36 and Fig. 26) revealed that the uptake of nitrogen was considerably higher in 1990 (126.2 kg/ha) than in 1989 (97.8 kg/ha).

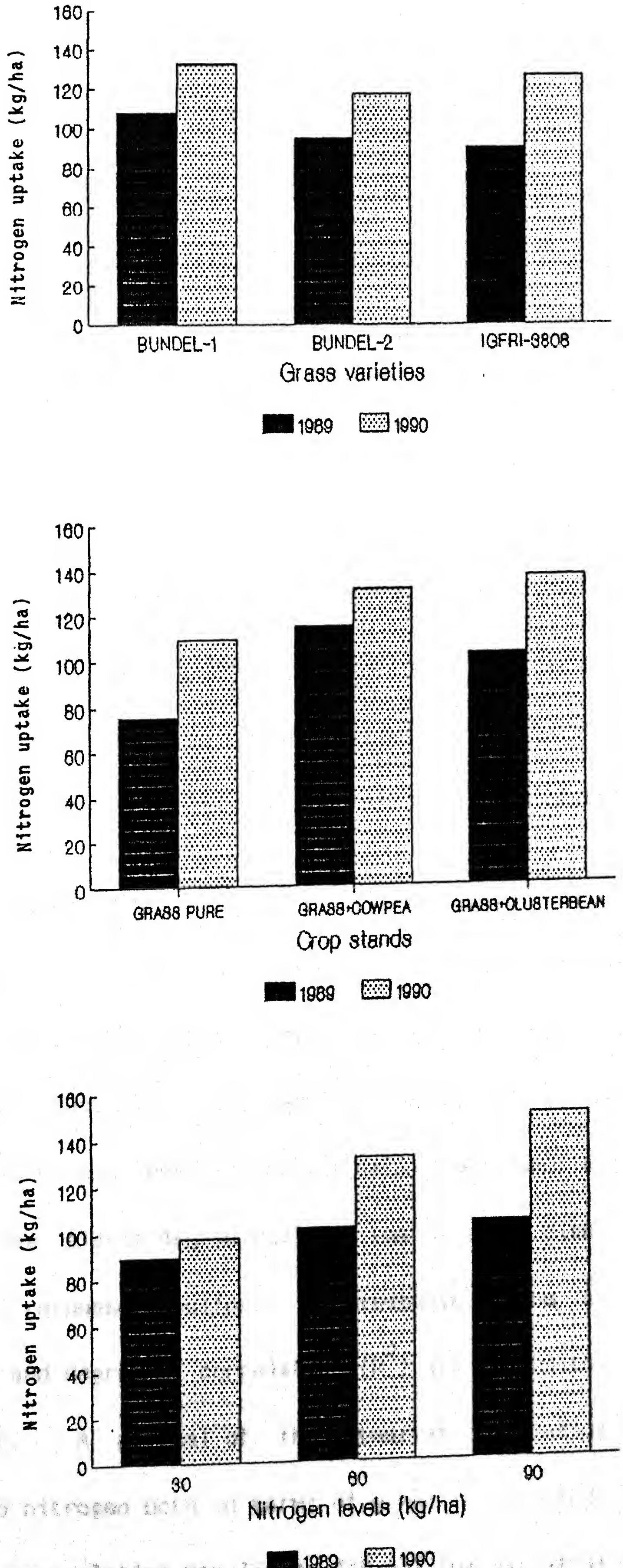
Pennisetum pedicellatum varieties differed significantly in nitrogen uptake only in 1989. Variety Bundel-1 showed significantly highest nitrogen uptake as compared to IGFRI-3808 which in turn did not differ significantly from Bundel-2. In 1990 also, the highest uptake of N occurred with Bundel-1 followed by IGFRI-3808. The similar trend was maintained with respect to average data.

Differential crop stands showed significant variation in N uptake and grass intercropped with clusterbean or cowpea caused significantly greater uptake of N as compared to pure grass in both the years. However, variation in nitrogen uptake between grass + cowpea and grass + clusterbean was not significant in both the years. In 1989, highest nitrogen uptake was observed with grass + cowpea but in 1990 it was higher with grass + clusterbean. The data averaged over the years indicated highest

Table 36. Nitrogen uptake (kg/ha)

Treatments	1989 Grass+Legume	1990 Grass+Legume	Mean Grass+Legume
Pennisetum pedicellatum varieties			
IGFRI-S-43-1 (Bundel-1)	107.7	132.8	120.3
IGFRI-S-4-2-1 (Bundel-2)	95.0	118.1	106.6
IGFRI-3808	90.8	127.8	109.3
SEm±	5.12	4.93	
CD at 5%	15.0	NS	
Crop stands			
Pennisetum pedicellatum pure	75.4	109.4	92.4
Pennisetum pedicellatum + cowpea	115.5	131.9	123.7
Pennisetum pedicellatum + clusterbean	102.6	137.4	120.0
SEm±	5.12	4.93	
CD at 5%	15.0	14.5	
Nitrogen levels (kg/ha)			
30	89.2	97.7	93.5
60	101.1	131.4	116.3
90	103.2	149.6	126.4
SEm±	5.12	4.93	
CD at 5%	NS	14.5	
General mean	97.8	126.2	

FIG 26: NITROGEN UPTAKE (kg/ha) OF SWARD



nitrogen uptake with grass + cowpea followed by grass + clusterbean intercropping.

Though the increasing nitrogen levels increased the nitrogen uptake in both the years, but the differences were significant only in 1990 where every additional dose of nitrogen increased the uptake significantly. The data averaged over the years, also indicated that nitrogen uptake progressively increased with the increasing levels of nitrogen up to 90 kg N/ha.

The interaction of varieties x crop stands (Table 37) showed significant variation in N uptake in 1989. Grass variety Bundel-1 intercropped with cowpea showed significantly higher N uptake as compared to other combinations. Further, all the grass varieties in association with cowpea or clusterbean showed significantly higher N uptake over their pure counterparts.

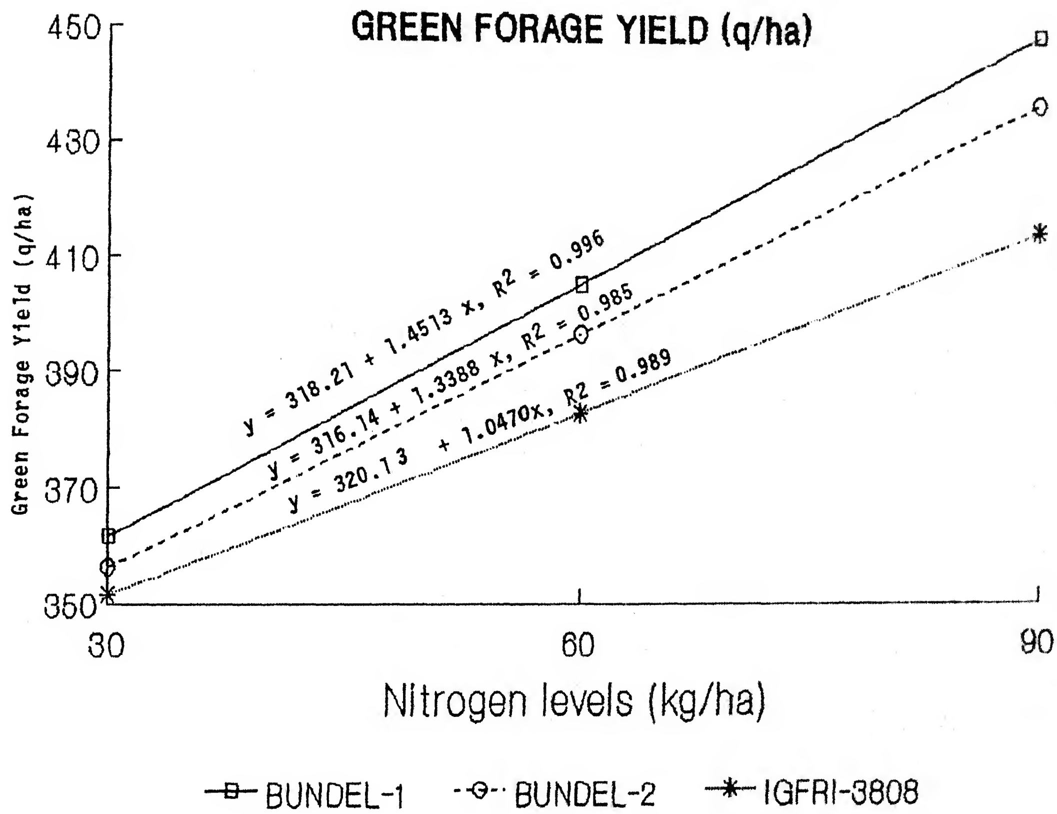
Response Functions:

In order to study the response behaviour of *Pennisetum pedicellatum* varieties in pure stand as well as intercropped with cowpea and clusterbean to varying levels of nitrogen, the response equations were fitted for both green and dry matter yields. The single degree analysis was done to find out the nature of response functions. The response curves along with equations and degree of correlation (R^2) are presented in Fig. 27 and 28. A perusal of the observations indicated that response to nitrogen both in terms of green forage production and dry matter accumulation was linear for all the varieties and crop

Table 37. Effect of crop stands X *Pennisetum pedicellatum* varieties on nitrogen uptake (kg/ha) in 1989

Crop stands	Varieties		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
Pennisetum pedicellatum pure	69.5	80.3	76.3
Pennisetum pedicellatum + cowpea	142.0	109.0	95.5
Pennisetum pedicellatum + clusterbean	111.5	95.7	100.6
SEm+	8.87		
CD at 5%	26.0		

FIG 27: RESPONSE FUNCTION OF GRASS VARIETIES



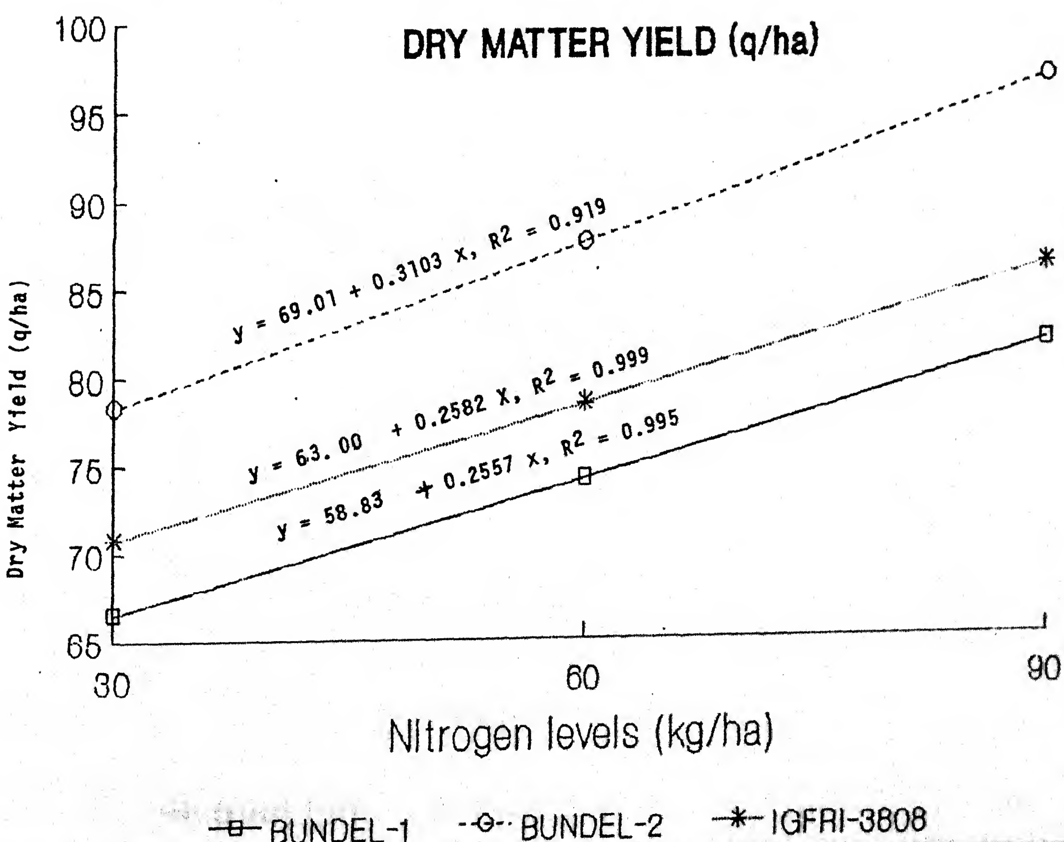
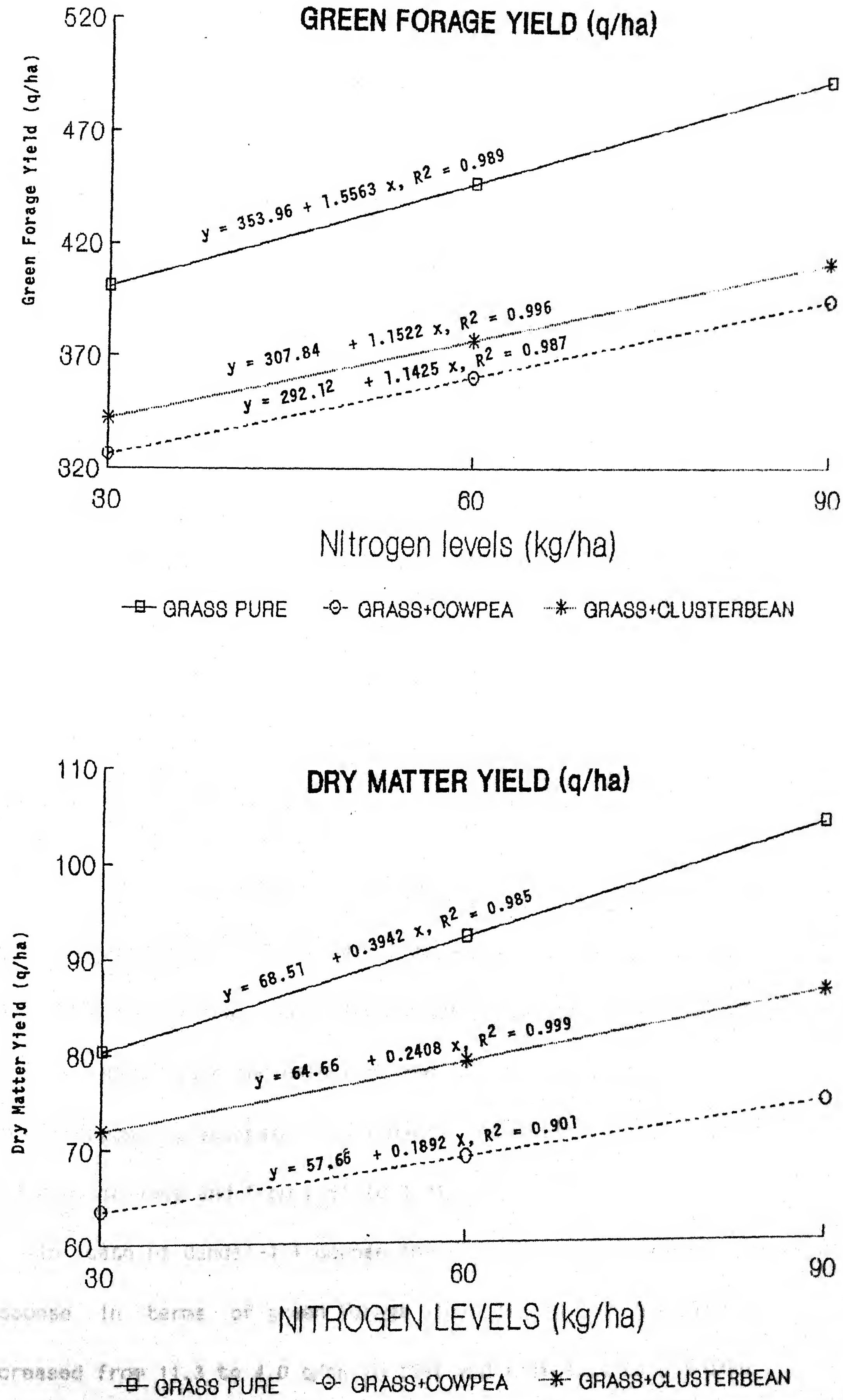


FIG 28: RESPONSE FUNCTION FOR CROP STANDS



stands. On an average, the degree of correlation measured as value of R^2 was maximum for variety Bundel-1 (0.996) for green forage and with variety IGFRI-3808 (0.999) for dry matter. The values of R^2 for variety Bundel-2 were lowest for green forage (0.985) and dry matter (0.919). Variety IGFRI-3808 for green forage and Bundel-1 for dry matter showed intermediate values of R^2.

Pennisetum pedicellatum + clusterbean exhibited maximum values of R^2 for both green forage (0.996) and dry matter (0.999) yields followed by pure grass stand. Dinanath + cowpea, however, gave lowest values of R^2 for green forage (0.987) and dry matter (0.901) yields.

The response to per kg of applied nitrogen varied from variety to variety and also with crop stands. However,the magnitude of response decreased with increasing doses of fertilizer nitrogen in all the varieties. The variety wise responses are discussed herewith.

Bundel -1: The response in terms of green forage yield in pure stand of Bundel-1 (Table 38) to each kg of applied N decreased from 10.9 to 4.3 q/ha when nitrogen was increased from 30 to 90 kg/ha in 1989. Such decrease was from 14.4 to 5.4 q/ha in 1990. The corresponding decrease in dry matter yield was from 1.19 to 0.78 q/ha in 1989 and from 2.81 to 1.31 q/ha in 1990.

In case of Bundel-1 + cowpea intercropping, the degree of response in terms of green forage yield per kg of applied N decreased from 11.3 to 4.0 q/ha in 1989 and from 12.0 to 5.4 q/ha

Table 38. Response of *Pennisetum pedicellatum* variety Bundel-1 to per kg of applied nitrogen (q/ha)

Nitrogen levels (kg/ha)	1989			1990		
	Pennisetum pedicellatum pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean	*Pennisetum pedicellatum* pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean
			Green forage			
30	10.9	11.3	10.1	14.4	12.0	13.3
60	6.2	5.7	5.5	9.2	7.4	7.1
90	4.3	4.0	4.1	6.7	5.4	5.4
			Dry matter			
30	1.91	2.10	1.90	2.81	2.0	2.47
60	1.10	1.14	1.14	1.51	1.27	1.34
90	0.78	0.77	0.77	1.31	0.73	1.07

in 1990 with increasing levels of nitrogen from 30 to 90 kg/ha. The dry matter yield of grass + cowpea per kg of applied N decreased from 2.1 to 0.77 q/ha in 1989 and from 2.0 to 0.73 q/ha in 1990. The green forage yield of grass + clusterbean per kg of applied N decreased from 10.1 to 4.1 q/ha in 1989 and from 13.3 to 5.4 q/ha in 1990. On the other hand, the dry matter yield of sward per kg of applied N decreased from 1.90 to 0.77 q/ha in 1989 and from 2.47 to 1.07 q/ha in 1990.

Bundel-2: The response in terms of green forage yield of this grass variety in pure stand (Table 39) to per kg of applied N decreased from 12.1 to 4.5 q/ha with an increase in nitrogen from 30 to 90 kg/ha in 1989 and from 14.2 to 6.9 q/ha in 1990. The corresponding decrease in dry matter yield was from 2.84 to 1.02 in 1989 and from 2.95 to 1.60 q/ha in 1990.

The response in terms of green forage yield of Bundel-2 + cowpea mixture to per kg of applied N decreased from 8.6 to 3.2 q/ha in 1989 against 12.2 to 5.2 q/ha in 1990. However, the decrease in dry matter yield was from 1.98 to 0.73 q/ha in 1989 and from 2.45 to 0.95 q/ha in 1990. In case of grass + clusterbean intercropping, the degree of response for green forage yield per kg of applied N decreased from 10.6 to 3.7 q/ha in 1989 and from 12.5 to 5.2 q/ha in 1990. The corresponding decrease in dry matter yield was from 2.42 to 0.91 q/ha in 1989 and from 2.76 to 1.10 q/ha in 1990.

Table 39. Response of *Pennisetum pedicellatum* variety Bundel-2 to per kg of applied nitrogen (q/ha)

Nitrogen levels (kg/ha)	1989			1990		
	Pennisetum pedicellatum pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean	*Pennisetum pedicellatum* pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean
			Green forage			
30	12.1	8.6	10.6	14.2	12.2	12.5
60	6.5	4.7	5.4	8.8	7.2	8.0
90	4.5	3.2	3.7	6.9	5.2	5.3
			Dry matter			
30	2.84	1.98	2.42	2.95	2.45	2.76
60	1.69	1.09	1.27	2.14	1.44	1.60
90	1.02	0.73	0.91	1.60	0.95	1.10

IGFRI-3808: The degree of response in terms of green forage yield in pure stand of IGFRI-3808 (Table 40) to each kg of applied N diminished from 11.4 to 4.4 q/ha when nitrogen was enhanced from 30 to 90 kg/ha in 1989. Such decrease was from 16.4 to 5.9 q/ha in 1990. The corresponding reduction in dry matter production was from 2.25 to 1.05 q/ha in 1989 and from 3.06 to 1.10 q/ha in 1990.

The green forage yield of IGFRI-3808 + cowpea per kg of applied N decreased from 8.8 to 3.4 q/ha in 1989 and from 11.6 to 4.9 q/ha in 1990. In case of dry matter yield, the reduction was from 2.07 to 0.77 q/ha in 1989 and from 1.95 to 0.92 q/ha in 1990. Grass + clusterbean intercropping showed that the response in terms of green forage yield to each kg of applied N decreased from 10.8 to 3.9 q/ha in 1989 and from 10.8 to 5.0 q/ha in 1990. On the other hand, the dry matter yield of grass + clusterbean sward per kg of applied N decreased from 2.49 to 0.98 in 1989 and from 2.29 to 0.91 q/ha in 1990.

Average response to nitrogen: The data on average response per kg of applied nitrogen to different *Pennisetum pedicellatum* varieties grown as pure stand and intercropped with cowpea and clusterbean have been presented in Table 41.

Pure grass stand: The data indicated that at 30 kg N/ha variety IGFRI-3808 as pure stand produced (13.2 q/ha) and Bundel-1 (12.7 q/ha). On the other hand, variety Bundel-2 produced maximum dry matter of 2.90 q/ha followed by IGFRI-3808 (2.66 q/ha) and

Table 40. Response of *Pennisetum pedicellatum* variety IGFRI-3808 to per kg of applied nitrogen (q/ha)

Nitrogen levels (kg/ha)	1989			1990		
	Pennisetum pedicellatum pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean	*Pennisetum pedicellatum* pure	*Pennisetum pedicellatum* + cowpea	*Pennisetum pedicellatum* + clusterbean
				Green forage		
30	11.4	8.8	10.8	16.4	11.6	10.8
60	6.1	4.7	5.5	8.8	7.1	6.7
90	4.4	3.4	3.9	5.9	4.9	5.0
				Dry matter		
30	2.25	2.07	2.49	3.06	1.95	2.29
60	1.33	1.07	1.26	1.67	1.22	1.34
90	1.05	0.77	0.98	1.10	0.92	0.91

Table 41. Average response to per kg of applied N (q/ha) of grass grown as pure and intercropped with cowpea/clusterbean

Nitrogen levels (kg/ha)	Pure stand			Grass + cowpea			Grass + clusterbean		
	Varieties			Varieties			Varieties		
	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808	IGFRI-S-43-1	IGFRI-S-4-2-1	IGFRI-3808
					Green forage				
30	12.7	13.2	13.9	11.7	10.4	10.2	11.7	11.6	10.8
60	7.7	7.7	7.5	6.6	6.0	5.9	6.3	6.7	6.1
90	5.5	5.7	5.2	4.7	4.2	4.2	4.8	4.5	4.5
					Dry matter				
30	2.36	2.90	2.66	2.05	2.22	2.01	2.19	2.59	2.39
60	1.31	1.92	1.50	1.21	1.27	1.15	1.24	1.44	1.30
90	1.05	1.31	1.08	0.75	0.84	0.85	0.92	1.01	0.95

Bundel-1 (2.36 q/ha). At 60 kg N/ha, the response to each kg of applied N was highest in Bundel-1 and Bundel-2 (7.7 q/ha) in terms of green forage yield and with Bundel-2 in terms of dry matter yield (1.92 q/ha). At highest level of 90 kg N/ha, the response to per kg of N applied in terms of green forage yield was found maximum with Bundel-2 (5.7 q/ha) followed by Bundel-1 (5.5 q/ha). In terms of dry matter yield also, variety Bundel-2 gave a lead (1.31 q/ha) over others.

Grass + cowpea: The response to per kg of applied N to grass + cowpea mixed stand indicated that at all levels of nitrogen application from 30 to 90 kg/ha, variety Bundel-1 produced highest green forage (11.7 to 4.7 q/ha) followed by Bundel-2 (10.4 to 4.2 q/ha). The corresponding dry matter was higher (2.22 q/ha) in Bundel-2 followed by Bundel-1 (2.05 q/ha) at 30 and 60 kg N/ha. However, at 90 kg N/ha variety IGFRI-3808 in association with cowpea produced highest (0.85 q/ha) dry matter yield followed by variety Bundel-2 + cowpea (0.84 q/ha).

Grass + clusterbean: The data averaged over the years indicated that at 30 and 90 kg N/ha, variety Bundel-1 in association with clusterbean produced higher green forage yield. However, at 60 kg N/ha the mixed stand with variety Bundel-2 produced higher yield per kg of applied N. In terms of dry matter variety Bundel-2 + clusterbean maintained highest degree of response at all the levels of fertilizer nitrogen from 30 to 90 kg/ha.

DISCUSSION

DISCUSSION

Growth and Forage Yield of Component Crops in Relation to Weather Conditions:

The forage production per unit area per unit time is a resultant of the interaction between genotypes and environment. The environmental factors influence the structural (morphological) and functional (physiological) responses of plants in a coordinated manner to determine the level of crop yield. In the present investigation the average total (grass+legume) green forage (455.2 q/ha) and dry matter (87.4 q/ha) yields (Table 17 and Fig. 12 and 13) were higher in 1990 as compared to 1989 (334.8 q green and 73.3 q dry matter/ha). The pooled analysis of the data brought out significant variation in forage yield due to years indicating that the weather conditions exhibited a strong bearing on the growth performance and forage production of component crops. This was also reflected in considerable variation in herbage productivity as the green productivity was 5.4 q/ha /day in 1990 against 4.2 q/ha/day in 1989. This was attributed to favourable weather conditions in 1990.

The total rainfall during the crop season was higher in 1990 (844.1 mm) as compared to 1989 (487.5 mm). The total rainfall for crop period was received in 31 rainy days in 1990 against 15 rainy days in 1989 indicating that the number of rainy days was more than double in 1990.

Thus, the uniform distribution of rainfall accompanied with higher humidity in 1990 influenced the crop growth favourably (Chatterjee, 1973). Contrary to this, the year 1989 experienced critical dry spells, beginning from standard week No. 30 for a period of two weeks immediately after sowing which adversely affected the germination and establishment of component crops. Again the second long dry spell occurred from standard week No. 36 from 3rd September till the harvest of crops. This coincided with active grand growth period of crops resulting in low herbage yield. The maximum and minimum temperatures as well as evaporation beyond standard week No. 35 also remained higher in 1989 as compared to 1990. All these caused soil moisture stress coinciding with establishment stage and grand growth period in 1989 which adversely affected the number of functional leaves, length and breadth of leaf, leaf area index, leaf:stem ratio and relative leaf turgidity of the grass component. In turn, all these reflected in lower herbage yield per unit area per unit time in 1989 as compared to 1990.

Growth and Forage Productivity of *Pennisetum pedicellatum* Varieties:

The variation in green forage production of *Pennisetum pedicellatum* varieties was not significant in both the years. However, on the basis of pooled data, Bundel-1 outyielded both Bundel-2 and IGFRI-3808 in green forage production. On the other hand, Bundel-2 accumulated significantly higher dry matter as compared to Bundel-1 and IGFRI-3808 which in turn did not differ

significantly between themselves. Since, variety Bundel-1 maintained higher relative leaf turgidity than others at harvest, it resulted in greater green forage yield and productivity per unit area. Variety Bundel-1 contributed 56.4 % to the total green forage yield against 63 % by Bundel-2 and IGFRI-3808. The contribution of counterpart legumes was 43.6 % in case of Bundel-1 and about 37 % with Bundel-2 and IGFRI-3808. These observations indicate that Bundel-1 exhibited better association with companion legume than Bundel-2 and IGFRI-3808. Moreover,the legumes intercropped with Bundel-1 also exhibited greater number of plants per running metre, increased number of functional leaves per plant and higher dry matter accumulation. All these favoured high total (grass+legume) forage yield with Bundel-1.

Significantly greater dry matter accumulation with variety Bundel-2 is due to proportionately higher contribution from grass (68.5 %) than from legume (31.5 %) and higher contribution of grass is on account of greater number of leaves per shoot and comparatively higher leaf area index attributing to greater photosynthesizing surfaces and thereby, higher dry matter accumulation (Brown and Blaser, 1968). These findings corroborate with those obtained under All India Coordinated Research Project on Forage Crops (AICRPFC, 1984-85). All these ultimately lead to higher productivity per day in terms of green and dry matter yield (Table 18 and Fig. 14 and 15).

Effect of Nitrogen Nutrition on Growth and Forage Yield:

The increasing doses of nitrogen from 30 to 90 kg/ha significantly increased the green and dry matter production in both the years as also on the basis of pooled data with the result that highest forage yield was obtained at 90 kg N/ha (Table 17 and Fig. 12 and 13). The positive effect of nitrogen nutrition in enhancing the green and dry matter yield is associated with an increase in growth attributes such as number of tillers, plant height, number of functional leaves of grass component as well as leaf area index and dry matter content (Table 3, 4, 8, 9 and 10 and Fig. 3, 4, 5, 6 and 7). This is because of the fact that nitrogen is involved in increasing protoplasmic constituents and accelerating the process of cell division and elongation which in turn give luxuriant vegetative growth for higher forage productivity (Watson, 1952).

Tregubenke and Filippov (1966) found an increase in the amount of most strongly bound water and water potential of leaf cells by increasing the nitrogen-phosphorus nutrition. Nitrogen nutrition induces an enhancement in the water retaining forces of the cell and reduces the rate of transpiration in the leaves and ultimately stimulates growth, resulting in better crop yield. Singh (1980) also reported that nitrogen nutrition enhances the growth and yield of maize by stimulating various metabolic processes. Nitrogen is the key element in grass growth and is the most limiting nutrient in the Indian soils. Its application not

only increases the green and dry matter yields but also influences the quality (Menhi Lal and Tripathi, 1987 a) of forage, particularly the level of protein. The favourable effects of nitrogen on growth attributes (plant height and number of leaves), quality parameters (protein and fat) and herbage yield of sorghum have been reported by Bajwa *et al.* (1983), EL-Kassaby (1985) and Wani *et al.* (1991).

Effect of Pure and Mixed Stands of *Pennisetum pedicellatum* on Growth and Forage Yield:

Pure stand of *Pennisetum pedicellatum* significantly out-yielded Dinanath grass + cowpea and Dinanath grass + clusterbean in green as well as dry matter production in both the years. Comparatively lower yield in intercropping system may be attributed to 50 % replacement (2:2 row ratio) of grass by legumes having relatively less production potential. This is however, compensated by improvement in forage quality particularly in terms of crude protein content of both the component crops and its total outturn in the sward. However, both the intercropping systems differed significantly between themselves in dry matter accumulation but not in green forage production. Significantly highest green and dry matter yield in pure stand is attributed to more number of shoots per running metre and higher leaf:stem ratio. Dinanath grass + clusterbean showed an edge over Dinanath grass + cowpea in green forage and dry matter yield. Such differences in the productivity are

associated with better plant height, LAI, RWC, root mass of grass in association with clusterbean than cowpea. Moreover, higher dry matter content of clusterbean also contributed to higher dry matter production of this combination.

The contribution of grass to total herbage production was 66.0 % with clusterbean against 55-60 % with cowpea. The better associative effect of clusterbean with grass in comparison to cowpea is primarily due to erect nature of growth of clusterbean which lends favourable environment for grass growth in mixed stand. Tripathi *et al.* (1984) also observed higher dry matter yield with Dinanath grass + clusterbean than Dinanath grass + cowpea.

Effect of Treatment Variables on Quality Traits:

Crude protein: All nitrogenous substances contained in feed stuff which include the true proteins (composed of a number of amino-acids) and non-protein nitrogen (NPN) compounds, are collectively called crude protein. *Pennisetum pedicellatum* variety Bundel-1 showed significantly higher crude protein content in both the years (Table 20 and Fig. 16) and crude protein yield in 1989 (Table 22 and Fig. 17). The higher crude protein content and yield of Bundel-1 at low and medium level of nitrogen is due to its longer leaf area duration and greater relative leaf turgidity maintained in this variety at harvesting stage. Moreover, the associated legumes by virtue of its higher number of leaves as well as greater degree of nodulation supplemented considerably in

improving the crude protein content in this variety. The favourable effect of associated legume on quality traits of grass may be attributed to nitrogen fixed by the intercrop legume and its transfer to the associated cereal component (Agboola and Fayemi, 1972; Remison, 1978; Eaglesham *et al.*, 1981; Pandey and Pendleton, 1986). Moreover, roots and nodules have been regarded as important sources of N transfer because of their high N contents on one hand (Butler and Bathurst, 1956) and nitrogen supplying power to associated cereal crops on the other (Henzell and Vallis, 1977; Herridge, 1982).

The intercropping of Dinanath grass with forage legume caused an increase in crude protein content of grass component. On an average Dinanath grass intercropped with cowpea contained 7.2 % crude protein against 6.9 % when intercropped with clusterbean and 6.3 % in pure grass stand. The total outturn of crude protein was also higher with Dinanath grass variety Bundel-1 + cowpea combination in 1989 than Dinanath grass + clusterbean. This kind of variation in crude protein yield is an outcome of proportionately greater contribution of cowpea containing higher level of crude protein (Menhi Lal and Tripathi, 1987 b). Moreover, 3.5 times greater number of nodules higher leaf:stem ratio and leaf turgidity of cowpea in comparison to clusterbean lead to greater contribution to crude protein yield. In 1990, Dinanath grass + clusterbean showed marginally an edge over Dinanath grass + cowpea in crude protein yield due to relatively higher green and dry forage yield.

Nitrogen nutrition influenced the level of crude protein favourably up to 60 kg N/ha in 1989 and up to 90 kg N/ha in 1990. The increase in crude protein content with increasing levels of fertilizer nitrogen is an expression of the part played by nitrogen in protein synthesis (Abraham *et al.*, 1980). Increase in crude protein content of Dinanath grass following nitrogen application was also reported by Narwal *et al.* (1977). Considerable evidences are available to show the key role of fertilizer nitrogen in increasing crude protein content and forage quality (Oberoi, 1980: Mannikar, 1980).

Water soluble carbohydrates(WSC): Glucose, fructose, sucrose and fructans are the main WSC in grass. Oligosaccharides other than sucrose have been detected but it is doubtful if these are present in significant quantity (Butler and Bailey, 1973). Soluble carbohydrates are important in helping to prevent *hypomagnesemia* and perhaps *hypocalcemia*. Metson *et al.* (1976) believed that the protective role of readily available carbohydrates may be partly due to their role in providing essential energy and carbon requirements for fatty acid and protein synthesis.

There was significant variation in WSC contents of *Pennisetum pedicellatum* varieties in both the years. Variety IGFRI-3808 contained highest WSC content (5.1 %) in 1989, whereas, in 1990, variety Bundel-1 exhibited highest WSC content of 3.9 per cent. The higher WSC content in variety IGFRI-3808 is

associated with its high photosynthetic rate as a function of more number of tillers, taller plant height and greater leaf area index. Forage legumes intercropped with *Pennisetum pedicellatum* variety IGFRI-3808 consistently exhibited higher WSC content on account of higher relative leaf turgidity resulting into longer period of carbohydrate synthesis with this combination.

Pennisetum pedicellatum and cowpea when grown in association accumulated significantly higher WSC than the pure grass stand in both the years. The higher WSC content with this combination is a resultant of their photosynthesizing characters viz., greater number of leaves and leaf:stem ratio in grass component and taller plant height, greater number of leaves, more leaf:stem ratio and increased leaf turgidity in legume component. In 1990, in intercropping, *Pennisetum pedicellatum* with cowpea gave highest WSC content at 30 kg N/ha whereas, with clusterbean WSC content was highest at 90 kg N/ha (Table 25). This could be substantiated by the fact that cowpea with better nodulation and nitrogen fixing characteristics caused associated grass to maintain higher level of WSC content at low (30 kg/ha) nitrogen dose. On the contrary, the grass associated with clusterbean, possessing comparatively less nodulation and nitrogen supplying power, demanded high nitrogen (90 kg/ha) to give maximum WSC content.

In general, increasing levels of fertilizer nitrogen from 30 to 90 kg/ha increased the content of WSC in Dinanath grass but decreased in forage legumes. Variety Bundel-1 consistently gave

higher WSC content at 90 kg N/ha. The increase in WSC of grass is linked with metabolic role of nitrogen in photosynthetic process (Singh, 1980). On the other hand, decrease in WSC content of legume is due to simultaneous increase in crude protein content which is inversely related to carbohydrates content (Thakre, 1987).

Oxalate content: Oxalic acid is one of the toxic substances occurring naturally in *Pennisetum* and *Setaria* species. These anti-quality substances cause direct metabolic damage to the animal or interfere with some phase of digestive utilization (Butler and Bailey, 1973). Excess of oxalate in feeds and fodders depletes body calcium of animal in the form of calcium oxalate, develops renal malfunctions and various other syndromes in ruminants.

Pennisetum pedicellatum variety Bundel-2 consistently gave lowest oxalate content even at 30 kg N/ha. On the other hand, variety Bundel-1 exhibited highest oxalate content in both the years. Variety IGFRI-3808 occupying intermediate position in this respect showed declining trend in oxalate content with each additional dose of fertilizer nitrogen. In general, increasing doses of nitrogen from 30 to 90 kg/ha decreased the oxalate content.

The association of forage legume in reducing the oxalate content of Dinanath grass was observed in relatively dry year (1989) but not in wet year (1990) and more so, the effect was

pronounced in association with cowpea. Intercropping high yielding grass species with suitable forage legumes has been reported to reduce anti-quality factors like oxalates in hybrid napier, besides providing balanced and nutritious herbage to animals (Tiwana and Bains, 1976; Patel *et al.*, 1973).

Fibre fractions: Crude fibre represents the frame work of the plants and includes cellulose, hemicellulose and lignin fractions of the cell wall. Neutral detergent fibre (NDF) is an estimate of cell wall content and acid detergent fibre (ADF) is actually a measure of lignocellulose complex in the forage materials. *Pennisetum pedicellatum* variety Bundel-1 contained lowest percentage of most of the fibre fractions (NDF, ADF, cellulose and lignin) indicating that this particular variety does not become too fibrous even at flowering stage (Table 28, 29, 32 and 33 and Fig. 20, 21, 23 and 24). In other words, it maintains the desirable quality characteristics of higher intake and digestibility. Legumes in association with variety Bundel-1 indicated highest NDF, ADF and hemicellulose and lowest lignin and acid insoluble ash content . Forage legume in association with Bundel-2 indicated highest content of cellulose and lignin and minimum content of NDF and hemicellulose. Lowest ADF and cellulose content was observed in legumes intercropped with Dinanath grass variety IGFRI-3808 with highest content of lignin.

Dinanath grass grown as pure stand exhibited highest contents of NDF, ADF, cellulose, hemicellulose and acid insoluble ash. Intercropping clusterbean with *Pennisetum pedicellatum* reduced the contents of NDF, ADF and cellulose. On the other hand, cowpea intercropping caused a decrease in hemicellulose and acid insoluble ash in grass component.

Nitrogen nutrition had no significant and consistent effect on fibre fractions of *Pennisetum pedicellatum.* However, low NDF and hemicellulose content was observed at 90 kg N/ha whereas, minimum content of ADF and cellulose was observed at low to medium level of fertilizer nitrogen. In so far as the effect of nitrogen nutrition on fibre fractions of legume component was concerned, application of 30 kg N/ha resulted in lowest content of NDF, ADF, hemicellulose and cellulose. Nitrogen nutrition exhibited favourable effect in reducing lignin content of legumes in wet year but not in dry year.

Nitrogen Uptake in Relation to Treatment Variables:

On an average *Pennisetum pedicellatum* variety Bundel-1 caused higher uptake of nitrogen in both the years. This was followed by Bundel-2 in 1989 and by IGFRI-3808 in 1990. The higher uptake of N by Bundel-1 is associated with its higher nitrogen content and greater proportion of nitrogen rich legume as compared to other varieties.

Nitrogen uptake remained higher in intercropping system as compared to pure stand of grass in both the years. Among

intercrops, the association of cowpea exhibited greater N uptake by sward than association of clusterbean. The change in the pattern of nitrogen uptake by grass varieties Bundel-2 and IGFRI-3808 and also by the intercropping systems over the years was an interplay of proportionate contribution of legume component to the total herbage yield (Henzell and Vallis, 1977; Herridge, 1982).

Increasing levels of nitrogen from 30 to 90 kg N/ha caused an increase in the uptake of nitrogen in both the years but the differences were significant only in 1990 when the magnitude of increase was of higher order. This was because of the fact that additional doses of nitrogen showed two fold benefits of increasing dry matter yield and improving the nitrogen content of grass component simultaneously. The advantages of nitrogen nutrition in enhancing the yield and quality of cereals have been reported by many workers (Oberoi, 1980; Mannikar, 1980; Menhi Lal and Tripathi, 1987 a; Tripathi and Singh, 1991).

Response to Fertilizer Nitrogen:

The response to applied nitrogen is a function of varietal characteristics and their associability with forage legumes in intercropping systems. The data on nitrogen response in relation to *Pennisetum pedicellatum* varieties and crop stands (Table 38 to 41) and (Fig. 27 and 28) indicated linear response to applied nitrogen for all the varieties. This therefore, suggests that within the range of 30 to 90 kg N/ha, the *Pennisetum pedicellatum*

varieties with differential growth rhythm responded linearly to nitrogen fertilization under rainfed environment. In view of linear nature of response functions, it was not possible to work out the optimum dose of fertilizer nitrogen. A linear increase in green and dry forage yields was also obtained with application of every additional dose of nitrogen over control treatment by Tiwari (1965), Sinha and Chatterjee (1966) and Narwal (1970). The studies conducted under All India Coordinated Research Project on Forage Crops (AICRPFC, 1975-76) also revealed significant effect of nitrogen nutrition on green forage yield of Dinanath grass up to 150 kg/ha at Kanke and Anand. However, in case of dry matter production the significant response occurred up to 150 kg N/ha at Kanke and up to 200 kg N/ha at Anand. At IGFRI Jhansi, higher green forage as well as crude protein yields of grasses have been obtained with application of nitrogen ranging from 30 to 90 kg/ha (Rai and Kanodia, 1981; Kumar *et al.*, 1979; Kumar et al., 1980: Dwivedi *et al.*, 1980).

The response to per kg of applied nitrogen varied from variety to variety and the degree of response decreased with increasing doses of nitrogen in all the varieties. Dinanath grass variety Bundel-2 registered the highest degree of response to each kg of fertilizer nitrogen specially in terms of dry matter production.

Production functions showed linear response of fertilizer nitrogen in relation to crop stands. However, the magnitude of response to each kg of applied nitrogen at all nitrogen levels

was higher in pure Dinanath grass than its association with cowpea or clusterbean. This suggests that association of legumes supplemented to the nitrogen requirements of associated grass species, thereby, showed lower degree of response in intercropping systems. Rai (1991) also revealed that the highest dry matter and crude protein yields were obtained with 60 kg N/ha in pure stand which were significantly higher than the yields obtained with mixed stand receiving up to 30 kg N/ha.

In intercropping system *Pennisetum pedicellatum* variety Bundel-1 exhibited highest response to per kg applied nitrogen in green forage production whereas, in dry matter production variety Bundel-2 excelled others.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The field investigation entitled "Forage yield and quality of *Pennisetum pedicellatum* varieties in relation to fertilizer nitrogen and intercrops" was conducted at Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi (UP) during *Kharif* season of 1989 and 1990. The experiment included three *Pennisetum pedicellatum* varieties (Bundel-1, Bundel-2 and IGFRI-3808), three crop stands (*Pennisetum pedicellatum* pure, *Pennisetum pedicellatum* + cowpea, *Pennisetum pedicellatum* + clusterbean) and three levels of nitrogen (30, 60 and 90 kg N/ha). These treatments were evaluated in 3^3 partial confounding design replicated twice with 6 blocks each of nine plots. The experimental findings have been summarised in the following sections.

Crop Growth, Forage Yield and Quality Traits in Relation to Weather Conditions:

The rainfall during crop period was 487.5 mm in 15 rainy days in 1989 and 844.1 mm in 31 rainy days in 1990. Thus, the uniform distribution of rainfall accompanied with higher humidity influenced the crop growth favourably in 1990. Contrary to this, the year 1989 experienced critical dry spells beginning from standard week No. 30 for a period of two weeks immediately

after sowing which affected the germination and establishment of component crops. Again, the second long dry spell occurred from standard week No. 36 from 3rd September till the harvest. This coincided with active grand growth period of crops resulting in low green and dry matter yields. The maximum and minimum temperatures as well as evaporation beyond standard week No. 35 also remained higher in 1989 as compared to 1990. All these caused soil moisture stress coinciding with establishment and grand growth period in 1989 which affected most of the growth characters viz., number of functional leaves, length and breadth of leaf, leaf area index, leaf:stem ratio and relative leaf turgidity of grass component. In turn this culminated in lower green forage (334.8 q/ha) and dry matter (73.3 q /ha) yields in 1989 as compared to 1990 (455.2 q/ha green forage and 87.4 q/ha dry matter). Moreover, dry year, 1989 produced forage with relatively higher dry matter content both of grass and legume components. The congenial weather conditions for component crops in 1990 also resulted in higher green forage (5.4 q/ha/day) and dry matter (1.0 q/ha/day) productivity as compared to 1989 (4.2 q/ha/day green forage and 0.9 q/ha/day dry matter).

The crude protein content of Dinanath grass was higher (7.1 %) in 1990 as compared to 1989 (6.5 %). Consequently, the crops caused greater uptake of nitrogen (126.2 kg/ha)in 1990 than in 1989 (97.8 kg/ha). The water soluble carbohydrates content, however, remained higher (4.8 %) in 1989 as compared to 1990

(3.5 %). The oxalate content in corresponding years was 2.8 and 3.2 per cent.

Among fibre fractions, plants contained relatively higher percentage of ADF, cellulose and lignin in 1990 whereas, the reverse was the trend with respect to NDF and hemicellulose. However, the differences were marginal. Acid insoluble ash (plant silica) content in grass was higher in 1990 (4.0 %) than in 1989 (2.6 %).

Growth Characters and Forage Yield in Relation to Treatment Variables:

Pennisetum pedicellatum varieties: *Pennisetum pedicellatum* variety Bundel-1 registered highest relative leaf turgidity percentage in dry year of 1989. Forage legume intercropped with this variety exhibited more number of functional leaves and root nodules in both the years. Variety Bundel-1 also accommodated greater number of plants with higher dry matter content of intercropped legume plants in 1989. On the basis of pooled data, variety Bundel-1 produced highest total green forage (405.6 q/ha) as well as resulted in maximum productivity (4.9 q/ha/day). This was followed by Bundel-2 with corresponding production levels of 396.5 q/ha and 4.8 q/ha/day. On an average, grass and legume contributed 56.4 and 43.6 per cent to the total herbage yield with this variety.

Variety Bundel-2 produced significantly higher total dry matter yield (87.6 q/ha) as compared to IGFRI-3808 (78.5 q/ha)

and Bundel-1 (75.0 q/ha) which, in turn, did not differ statistically from each other. The dry matter productivity of Bundel-2 was also higher (1.1 q/ha/day) as compared to remaining varieties (0.9 q/ha/day). In intercropping system, variety Bundel-2 and associated legume accounted for 68.5 and 31.5 % to the total dry matter accumulation. However, variety Bundel-2 resulted in greater number of functional leaves and higher dry matter content in both the years. This variety maintained greater leaf:stem ratio in 1989 and higher relative water content in 1990. Legume in association with this variety maintained higher leaf:stem ratio in 1989 and produced taller plants with greater dry matter accumulation in 1990.

On the other hand, *Pennisetum pedicellatum* variety IGFRI-3808 excelled other varieties in number of tillers, plant height and leaf area index in both the years. This variety also proved superior over others for root mass in 1989 and for leaf:stem ratio in 1990. Forage legume intercropped with *Pennisetum pedicellatum* variety IGFRI-3808 produced taller plants in 1989, higher leaf:stem ratio in 1990 and greater leaf turgidity in both the years.

Crop stands: Pure stand of *Pennisetum pedicellatum* produced taller plants in 1989, higher dry matter content in 1990 and more number of tillers with greater leaf:stem ratio in both the years. Dinanath grass in association with cowpea produced more number of

leaves, accumulated higher dry matter content and maintained higher leaf turgidity in 1989. On the other hand, in 1990, grass in association with clusterbean produced taller plants, higher relative leaf turgidity and greater leaf area index in both the years. Among intercrops, cowpea produced taller plants, greater number of leaves, higher leaf:stem ratio, increased relative leaf turgidity and greater number of root nodules. However, clusterbean accommodated more plants per running meter and accumulated higher dry matter content in both the years. On an average, pure Dinanath grass produced significantly highest total green forage (447.4 q/ha) as compared to grass + clusterbean (377.0 q/ha) and grass + cowpea (360.7 q/ha) which, in turn, did not differ significantly between themselves. In terms of dry matter yield, the crop stands differed significantly and the corresponding yield levels were 93.0, 79.2 and 69.0 q/ha. Similar trend was observed with respect to green and dry matter productivity per day.

Nitrogen levels: Application of 60 kg N/ha resulted in higher leaf area index in 1989, greater number of leaves with higher dry matter content in 1990 and more number of tillers with greater plant height as compared to 30 kg N/ha in both the years.

Nitrogen at 60 kg N/ha also produced greater number of functional leaves and more number of root nodules in

intercropped forage legume in both the years. Further, increase in nitrogen levels to 90 kg N/ha, however, produced greater number of functional leaves, accumulated higher dry matter in 1989 and resulted in greater leaf area index in 1990. In so far as the legume component was concerned, 90 kg N/ha accumulated higher dry matter content in 1989 and produced taller plants with high leaf turgidity in 1990.

Pooled data revealed that application of 90 kg N/ha significantly increased the green forage (430.1 q/ha) and dry matter (87.4 q/ha) yields as compared to 60 kg N/ha. The highest per day productivity in terms of green forage (5.2 q/ha/day) and dry matter (1.1 q/ha/day) was also obtained at 90 kg N/ha.

Quality Traits in Relation to Treatment Variables:

Crude protein: On an average the crude protein content both of grass (7.5 %) and legume (17.1 %) components remained highest with *Pennisetum pedicellatum* variety Bundel-1. This in turn, registered the highest outturn of crude protein (752.5 kg/ha) for the mixed sward. Intercropping of grass + cowpea not only recorded the highest crude protein content for individual component but also the total crude protein yield of the system.

The highest crude protein content was obtained at 60 kg N/ha for grass (6.8 %) and at 30 kg N/ha for legume (16.4 %) in dry year of 1989. In wet year of 1990, however, highest crude protein

content for both the component crops (7.9 % for grass and 17.4 % for legume) occurred at 90 kg N/ha. Increasing doses of nitrogen from 30 to 90 kg N/ha increased the total outturn of crude protein both in pure and mixed stands. Intercropping system of *Pennisetum pedicellatum* + cowpea and *Pennisetum pedicellatum* + clusterbean receiving 60 kg N/ha gave additional crude protein of 129.2 and 49.5 kg/ha, respectively over *Pennisetum pedicellatum* pure fertilized with 90 kg N/ha. This, therefore, indicated a saving of fertilizer nitrogen equivalent to 30 kg N/ha, besides providing protein rich nutritious herbage.

Water soluble carbohydrates (WSC): Variety IGFRI-3808 exhibited the highest WSC content of 5.1 % in 1989 whereas in 1990, variety Bundel-1 showed higher WSC content of 3.9 per cent. Forage legume intercropped with IGFRI-3808 consistently registered higher WSC content (3.6 %) than in association with other varieties. The grass grown in association with cowpea accumulated greater WSC content in both the years. Among intercrops, cowpea in 1989 (4.9 %) and clusterbean in 1990 (2.6 %) showed higher WSC content. On an average, the accumulation of WSC content was highest at 90 kg N/ha in grass (4.4 %) and at 30 kg N/ha in legume (3.5 %).

Oxalate content: Variety Bundel-2 accumulated the lowest oxalate content (2.8 %). The association of forage legume in reducing the oxalate content of Dinanath grass was observed in relatively dry year (1989) but not in wet year (1990) and more so, the effect

was pronounced in association with cowpea. In general, the application of 30, 60 and 90 kg N/ha gave an oxalate content of 3.2, 3.0 and 2.9 %, respectively indicating that nitrogen nutrition exercised favourable effect in reducing oxalate content of Dinanath grass.

Fibre fractions: *Pennisetum pedicellatum* variety Bundel-1 exhibited lowest percentage of NDF ,ADF, cellulose and lignin suggesting that this variety possesses desirable quality characteristics of higher intake and digestibility. However, Bundel-2 and IGFRI-3808 contained minimum plant silica and hemicellulose. Forage legume associated with Bundel-1 also gave lowest lignin content. Lower content of NDF, hemicellulose and plant silica occurred when legume was grown in association with Bundel-2. Grass contained minimum lignin in pure stand, plant silica with cowpea and NDF with clusterbean. No definite trend was observed with respect to remaining fibre fractions. Among intercrops, clusterbean exhibited lower content of NDF, hemicellulose, lignin and plant silica whereas cowpea gave low cellulose content.

The effect of nitrogen nutrition in modifying the fibre fractions of grass was variable. It follows that 90 kg N/ha reduced the content of NDF and hemicellulose whereas, the decrease in lignin content was observed at 30 kg N/ha. Acid

detergent fibre, cellulose and plant silica, however, remained unaltered due to nitrogen nutrition. In case of legume, lower contents of NDF, ADF, hemicellulose, cellulose and plant silica were observed at 30 kg N/ha whereas, minimum content of lignin occurred at 90 kg N/ha.

Response to Fertilizer Nitrogen:

On an average, *Pennisetum pedicellatum* variety Bundel-1 showed greater uptake of nitrogen (120.3 kg/ha) than remaining varieties. Among crop stands, *Pennisetum pedicellatum* + cowpea in 1989 and *Pennisetum pedicellatum* + clusterbean in 1990 registered significantly higher nitrogen uptake as compared to pure grass stand. Nitrogen uptake of the sward increased from 93.5 kg/ha with 30 kg N/ha to 126.4 kg/ha at 90 kg N/ha.

All the three *Pennisetum pedicellatum* varieties showed linear response to per kg of applied nitrogen both in pure as well as in mixed stands. However, variety Bundel-2 registered the highest degree of response to each kg of applied N and more so in dry matter production. The degree of response, however, decreased with increasing doses of fertilizer nitrogen with the result that average response to each kg of fertilizer N at 30, 60 and 90 kg N/ha worked out to be 11.8, 6.7 and 4.8 q/ha in terms of green forage. The corresponding responses in terms of dry matter yields were 2.4, 1.4 and 1.0 q/ha.

Conclusions:

1. *Pennisetum pedicellatum* variety Bundel-1 proved superior in green forage production, crude protein outturn and associability with forage legumes. Variety Bundel-2 produced the highest dry matter yield with the lowest oxalate content and ranked second in green forage as well as crude protein production.

Which one is the best variety?

2. All the *Pennisetum pedicellatum* varieties responded linearly to fertilizer nitrogen both in pure and mixed stands ranging from 30 to 90 kg N/ha. The maximum response to each kg of applied N occurred with Bundel-1 for green forage production and with Bundel-2 for dry matter accumulation.
3. Nitrogen nutrition had a distinct positive effect on increasing crude protein and water soluble carbohydrates and reducing oxalate in *Pennisetum pedicellatum*.
4. Intercropping of *Pennisetum pedicellatum* with forage legume showed superiority over its pure stand in terms of crude protein content and its outturn in the sward alongwith reduction in the firbre fractions of grass component. Moreover, intercropping of Dinanath grass + cowpea resultted in nitrogen economy equivalent to 30 kg fertilizer N/ha.

Recommendations:

Pennisetum pedicellatum variety Bundel-1 + cowpea with 60 kg N/ha and/or Bundel-2 + clusterbean with 90 kg N/ha may be recommended for achieving optimum forage yield, better quality traits and greater nutrient outturn.

Future Line of Research Work:

1. There is need to identify appropriate *Pennisetum pedicellatum* variety capable of maintaining quality even after boot stage with minimum or no risk of oxalate toxicity. The forage legume should be compatible with matching physiology to harness the positive associative effects. This will ensure ideal combination to optimise yield and quality in intercropping system.

2. Studies are required to develop nitrogen management techniques to activate N_2 fixation by forage legume in initial stage and to meet the increased nitrogen demand of grass during peak vegetative growth period.

3. Since, in intercropping system grass is able to extract potassium much more readily causing K starvation to legume, especially on K deficient soils, appropriate cutting-cum-potassium fertilizer schedules need to be worked out to supply enough K to legume without causing luxury consumption by the grass.

4. There is need to generate basic information on selectivity and availability of forms of nitrogen and fractions of phosphorus to grass and legume components, respectively in mixed stand.

5. The grass and legume components in combination cropping vary in species aggressivity, botanical composition and forage productivity. This causes considerable variation in chemical composition and mineral balances of the produce. Thus, there is need to find out appropriate grass-legume proportion to achieve the desired N:S, Ca:P and K:Mg ratios in mixed herbage in relation to animal requirement.

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